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Did Kekulé's dream reveal ring structure of benzene?
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NOVEMBER 4, 1985
CHEMICAL & ENGINEERING
NEWS

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ADHESIVE MONOMERS

Little growth forecast for phenol and vinyl acetate

A Key Chemicals Review Page 11

CHEMICAL & ENGINEERING
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NOVEMBER 4, 1985

Volume 63, Number 44
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News of the Week

■ **Monsanto restructuring entails $559 million writedown in fourth-quarter earnings.** **Page 6**

■ **Despite reports of Soviet buildup of chemical and biological arms, House fails to include funds for binary weapons in Defense appropriations bill.** **Page 7**

■ **Chemical information from CAS, other technical databases now available on laser-read compact disks.** **Page 8**

■ **Participants in ILO-sponsored meeting call for an international task force of safety and health experts to help prevent major industrial accidents.** **Page 8**

Cover: Photo courtesy of Celanese

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Concentrates

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Business

Demand for sulfur is increasing and markets will be tight through 1995; East bloc countries may become big exporters. **Page 14**

Government

Tax reform, federal deficit reduction, protectionist trade measures are topics of industry concern at CMA conference. **Page 17**

California allocates $20 million to clean up hazardous waste sites, most of it for Stringfellow acid pits. **Page 19**

Science

Did a dream lead Kekulé to propose a ring structure for benzene? Scientists debate the role of imagination in science. **Page 22**

Defense Department funds basic research, officials say, but many scientists are unaware of nonmission-oriented projects. **Page 24**

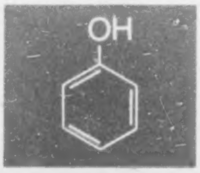
Technology

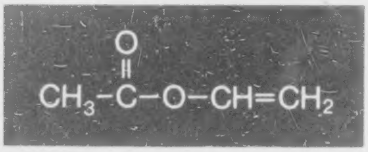
TVA center makes improvements in preventing ammonia loss from fertilizers, process for melt granulation of urea. **Page 28**

Varian's new VXR series of Fourier transform NMR spectrometers is latest advance in firm's profitable instrument line. **Page 33**

ACS News

Committee on Professional Relations details eight incidents of mass firings of chemical professionals. **Page 40**





$CH_3-\overset{\overset{O}{\|}}{C}-O-CH=CH_2$

Cover Story

Adhesives intermediates phenol and vinyl acetate have few prospects for growth as exports decline and domestic markets mature. **Page 11**

Growth Prospects Look Dim for Big-Volume Adhesive Intermediates

Maturing of most major end uses plus decline in exports makes capacity for phenol and vinyl acetate adequate for rest of 1980s

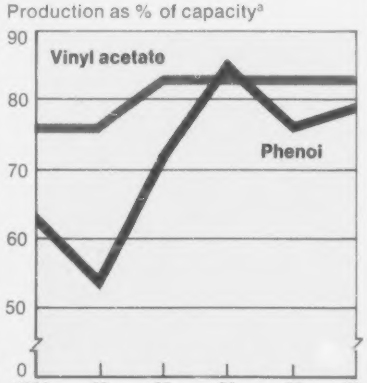
Bruce F. Greek, C&EN Houston

With the halt of years of hefty growth in demand for phenol and vinyl acetate, producers of these materials have been looking realistically at longer-term demand and need for capacity. These intermediates are of major importance for adhesives and are of significant importance for various coatings, plastics, and fibers, none of which now show much growth.

New developments to expand end uses of adhesives, coatings, plastics, fibers, and other, lesser-volume products have proved to be elusive. As a result, prospects for growth in demand for phenol and vinyl acetate rank no better than the growth in gross national product through the rest of this decade. Such prospects for low growth rates leave producers faced with severe competition, low profitability, and very little reinvestment money.

Since recession, plant capacity use has stabilized

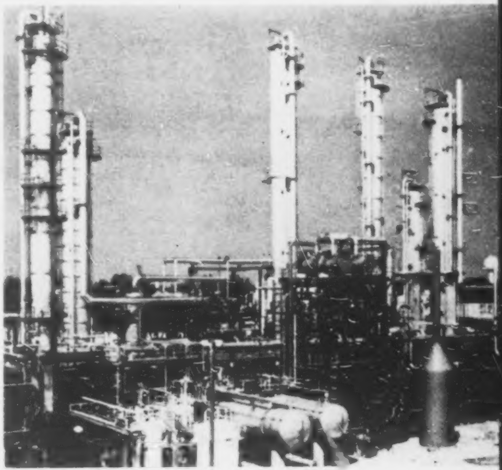
Production as % of capacity[a]



[a] First-quarter nameplate capacity. **Sources:** International Trade Commission, C&EN estimates

Bleak as the situation is, overcapacity for phenol and vinyl acetate isn't so bad as it is for some major-volume organic chemicals. With operating rates for these adhesive materials in the 75 to 85% range, there are no problems in meeting demand, unless raw materials become short. If demand growth falls between 1 and 3% annually on the average over the next five years, present capacity will be large enough to satisfy demand for the next several years.

A close examination of the situation for both these compounds reveals various differences, but the same conclusion remains—that sufficient capacity now exists to meet demand through 1990. Phenol production in 1985 will require an average operating rate of 75%. Even growth at 3% compounded for the next five years will not use up all of present capacity available for operation. Some phenol capacity, however, is quite old and may be scrapped because of its inefficiencies. Some recently announced expansions could partially or totally replace that scrappage.



General Electric's phenol complex in Mount Vernon, Ind.

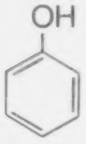
For vinyl acetate, the outlook hinges more on export markets. Exports, which once accounted for more than a quarter of production, long have been forecast to decline, and those forecasts have been reliable until this year. The decline in exports has offset the gains in U.S. consumption of vinyl acetate, thereby holding production relatively constant. In the future, after the minor anomaly of a possible slight rise in exports in 1985, more declines are forecast as new capacity to make vinyl acetate comes on stream in various countries that now are large buyers of U.S. product. Some of these new and expansive producers could become exporters on their own, which might further reduce U.S. exports to countries that are without vinyl acetate plants.

Imports of phenol and vinyl acetate are so small they have a negligible effect on U.S. markets, and they are forecast to remain small. Producers of these materials will focus more on domestic consumption—in view of declining exports. They then can assume GNP growth rates for the major mature end-use expansion and conclude that capacity for phenol and vinyl acetate will be adequate for longer than ever before.

For some details of the near-term outlook for phenol and vinyl acetate, please see the following pages.

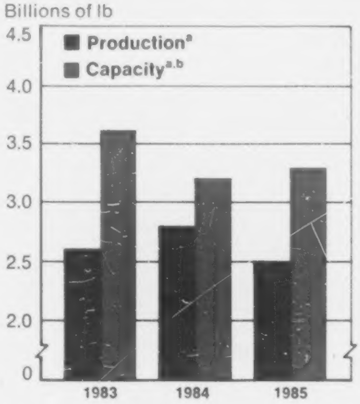
Key Chemicals

Phenol



- ***Demand slowing***
- ***Capacity may rise***
- ***Prices unsettled***

PRODUCTION/CAPACITY



a Synthetic only. **b** First quarter

MAJOR PRODUCERS

Allied-Signal, Dow Chemical, General Electric, Shell Chemical, USS Chemicals

HOW MADE

Peroxidation of cumene (isopropyl benzene) and cleavage to phenol and acetone

MAJOR DERIVATIVES (U.S.)

Resins (mostly with formaldehyde as comonomer) 40%, bisphenol A 20%, caprolactam 15%

MAJOR END USES (U.S.)

Adhesives 60%, plastics 20%

FOREIGN TRADE

Exports—holding at about 100 million lb, imports—rising to about 50 million lb

PRICE

About 34 cents a lb, freight-equalized

This year is a relatively poor one for phenol producers. Production will be down slightly, but profitability is falling severely. None of phenol's major end uses will grow very much in 1985, with a slowdown in construction accounting for most of the decline.

Synthetic phenol production in the U.S. will total about 2.5 billion lb this year, or possibly 2.6 billion lb if plywood producers anticipate improved demand for their product from an increase in housing starts in 1986.

Capacity to make phenol totals about 3.3 billion lb. That total includes world-scale plants with nameplate capacities of more than 500 million lb a year and small plants with capacities of less than 100 million lb a year. Moreover, several very small units operate to recover phenol from natural sources such as coal tar and petroleum fractions. These small units have a combined capacity of 50 million lb a year.

Capacity expansions for synthetic phenol production have been minor over the past year or more. No more than 100 million lb has been added to the total. As a result, plants will run at about 75% of capacity.

As usual, with an average operating rate of 75%, rumors have developed about possible plant shutdowns. The smaller plants always are the obvious candidates for scrappage, especially if they are old. However, many of the smaller units have some load from captive demand to make resins, similar to plants that produce natural phenol. Economics favor keeping such plants running, if marginal output can be sold on the merchant market.

The efforts to keep production up cause the major woe of the phenol business—low selling prices. Besides competitive pressures stemming from excess production, phenol producers also face pressure from buyers who expect lower prices as a result of a decline in benzene prices. Current benzene list prices are down about 10%, or about 15 cents per gal, from the recent highs. This decline in benzene prices puts about a 2 cent-per-lb price pressure on phenol alone.

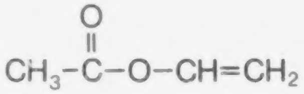
Consumption in making phenolic resins, mostly condensation polymers from the reaction of phenol and formaldehyde, is critical to phenol pricing and demand. These resins account for nearly 40% of phenol consumption in the U.S. About 85% of such resins are used as adhesives or binders, slightly more than half of which are used in making plywood and wood fiberboard. Therefore, construction effectively controls phenol demand.

The outlook for such construction now appears to be flat to slightly down. Recent monthly housing starts have declined, but so have interest rates for mortgages. Some industry sources expect that lower interest rates will increase housing starts in 1986, but others expect interest rates to rise because of the federal deficit. Plywood makers are warily watching their own inventories and the stocks further down the consumption chain toward construction in combination with interest rates. Apparently, some plywood inventory liquidation occurred earlier in 1985, reducing phenol demand for a time. Several phenol producers believe that inventories are relatively low in relation to current housing construction, so demand could increase in early 1986 if the housing market turns up.

Other uses of phenol, such as in making bisphenol A and caprolactam, will grow faster than will phenol-formaldehyde resins. Most bisphenol A goes into epoxy and polycarbonate resins, both of which continue to grow well. Caprolactam made from phenol goes mostly into making nylon 6, then into carpet fibers where demand remains fairly strong but heavily dependent on housing. Several miscellaneous uses of phenol take the remaining production. They range from making aniline that goes into polyurethanes to making 2,6-xylenol that becomes polyphenylene oxide plastics. None are very large, and none are growing fast enough to influence total demand.

Key Chemicals

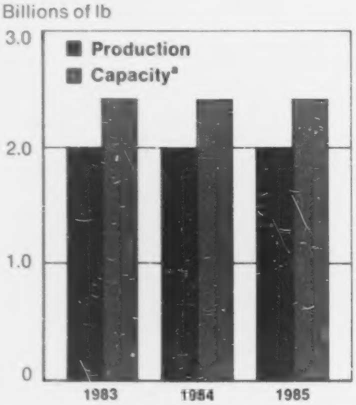
Vinyl acetate



$CH_3-C(=O)-O-CH=CH_2$

- ***Demand steady***
- ***Capacity on hold***
- ***Prices slightly better***

PRODUCTION/CAPACITY



a First quarter.

MAJOR PRODUCERS

Celanese, Du Pont, Union Carbide, U.S. Industrial Chemicals

HOW MADE

Vapor-phase reaction of ethylene, acetic acid, and oxygen

MAJOR DERIVATIVES (U.S.)

Polymers 55%, polyvinyl alcohol 20%, copolymers 15%

MAJOR END USES (U.S.)

Adhesives 40%, paints 25%, paper and textile coatings 20%

FOREIGN TRADE

Exports—more than 500 million lb, imports—small, about 1 million lb

PRICE

37 to 39 cents a lb, delivered

Production of vinyl acetate remains stagnant. Until 1985, however, U.S. consumption had been rising, but declining exports offset the increased consumption, holding production at about 2 billion lb for three years in a row.

In early 1985, exports had been increasing, suggesting that total production this year might rise above the 2 billion lb level. But as exports increased, domestic consumption began to drop in large-volume end uses such as paints and textile sizings. More recently, exports have been reported lower, suggesting that exports for the year will be close to 500 million lb, about the same as last year. Exports of vinyl acetate derivatives usually have added another 100 million lb or so.

No significant vinyl acetate capacity additions have been made in the past year. The capacity has been holding for the past four years and will hold through 1986 at 2.4 billion lb. The reason for lack of expansion remains obvious: absence of growth in demand for vinyl acetate and existing overcapacity. If production in 1985 totals 2 billion lb, then the plant operating rate will be 83% of capacity.

Almost all vinyl acetate eventually becomes some kind of polymer, of itself, with another monomer such as ethylene or vinyl chloride, or becomes polyvinyl alcohol, which is a derivative of polyvinyl acetate.

The largest-volume end use of vinyl acetate continues to be adhesives, accounting for about 40% of U.S. consumption. Major end uses are in packaging, construction, and consumer products. The packaging uses are dominated by corrugated paperboard, laminates, labels, and tapes. Construction uses are somewhat limited by strength properties, but major end uses include such items as wallboard tapes, laminates of polyvinyl chloride as coverings to gypsum board for prefinished panels, and direct adhesives. The consumer adhesive area includes glues for paper, wood, and plastics.

Many of the adhesive uses relate to the economy, so growth has a direct relationship to gross national product. Use in construction relates closely to housing, which has been having an unspectacular year with prospects for the first half of 1986 about the same, depending on interest rates.

Paints, which make up about a third of U.S. consumption of vinyl acetate, also are almost completely copolymers, most often made with various acrylates. Housing again dominates this use, but housing starts are not so great an influence on paint sales as they are on demand for other chemical products. This is because trade sales of paint for repainting houses reflect decisions other than just new housing. Even in times when new housing sales are down, paint trade sales, especially interior paints, hold up well. Vinyl acetate, plus 10 to 20% comonomers, has almost completely replaced alkyd resins in interior paints. Growth in use of vinyl acetate in semigloss trim paints for interior use and in exterior paints continues to be slower than the takeover of interior wall paints, but developments of polymers with a third comonomer to help weathering and stability to ultraviolet light will help vinyl acetate in exterior paints.

Because of the quality improvements and the trend toward smaller houses and living spaces, however, paint sales are expected to rise no faster than the GNP. Consequently, vinyl acetate demand growth in paints will range from zero to the same rate as the GNP.

Vinyl acetate for paper and textile coatings also is consumed as polymers, usually as a homopolymer, as a copolymer with minor quantities of a comonomer, or as polyvinyl alcohol. As might be expected from the high imports of apparel, textile coatings (sizings) as a use of vinyl acetate are down.

Paper coatings are growing well, however, because of efforts to improve quality of such products as printing papers, labels, and boxboard.

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Chemical earnings fall average of 19% in third quarter
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SPECTROSCOPY

Vibrational optical activity techniques become routine
Page 21

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News of the Week

- **Genetic engineering work at Monsanto brings scientists closer to conferring herbicide resistance on commercial crops.** **Page 4**
- **Neuroscience research institute, a collaboration of Italian drug firm Fidia and Georgetown University, begins operation.** **Page 5**
- **EPA approval of first field test of genetically engineered bacteria is expected this week.** **Page 5**
- **Second meeting on the Pimentel Report brings forth lively discussion on implementation efforts.** **Page 6**

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Business

Chemical industry earnings fell an average of 19% in the third quarter compared with year-earlier levels. **Page 10**

International Business

Canadian chemical companies in better shape than last year, with organics leading the upturn. **Page 16**

Government

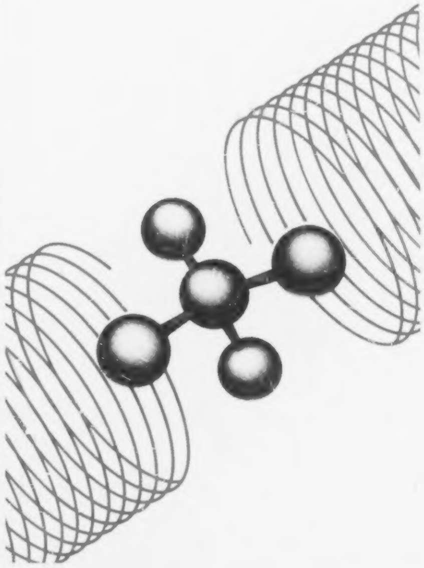
Bills setting fiscal 1986 funding levels for federal agencies are stalled in Congress, but not for lack of effort. **Page 18**

Technology

New microcomputer software from Laboratory Technologies Corp. analyzes chromatography data in production applications. **Page 33**

Books

"**Global Energy: Assessing the Future**" takes a look at long-term patterns in energy supply and use; "Hazardous and Toxic Materials: Safe Handling & Disposal" is primer on hazardous waste. **Page 35**



Science

Revolutionary new methods in spectroscopy make use of vibrational circular dichroism, Raman optical activity, and magnetic fields. **Page 21**

Chemical Earnings Fall For Fourth Consecutive Quarter

David Webber, C&EN New York

Bludgeoned by imports, hobbled by prices, and undermined by weak sectors of the economy, the chemical industry staggered through a third quarter that resulted in most cases in lower earnings from operations than in last year's third quarter. For several companies, extensive restructuring charges reduced the bottom line even further.

Taking into consideration operations alone, net income in the chemical industry declined an average of 19% in third-quarter 1985 from the year-earlier period, based on the results of 29 of the 30 largest chemical producers. (The other firm, Chesebrough-Pond's, is excluded from this and other composite calculations because its acquisition of Stauffer Chemical in March renders year-to-year comparisons meaningless at this time.) The group's aggregate sales were about the same as a year earlier. It was the fourth consecutive quarter in which the group's earnings total fell compared to the year before.

Many companies in a group of 21 diversified manufacturers with substantial chemical operations also reported sales and earnings declines in the quarter. Most likewise reported poor to mediocre performance by their chemical segments, and aggregate net income for the group, buffered somewhat by nonchemical results, dropped 4%. Sales were down 2%, compared to third-quarter 1984.

Poor performance by petrochemical product lines also compounded the woes of energy companies, already hurting from the oil slump. A group of 17 reported that composite third-quarter net income de-

Chemical industry leaders for the third quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1985		$ Millions	Rank 1984		$ Millions	Rank 1984		Earnings as % of sales	Rank 1984
1	Dow Chemical	$2873.0	1	Dow Chemical	$107.0	1	International Flavors	14.3%	1
2	Union Carbide	2254.0	2	PPG Industries	73.9	4	Freeport-McMoRan	11.0	3
3	Monsanto	1741.0	4	Union Carbide	58.0	3	Nalco Chemical	11.0	2
4	W. R. Grace	1734.3	3	Celanese	47.0	8	Ethyl	9.1	6
5	PPG Industries	1040.0	5	Air Products	38.1	12	Air Products	8.0	11
6	American Cyanamid	852.3	6	Ethyl	35.1	9	Loctite	7.8	4
7	Celanese	758.0	7	Rohm & Haas	34.8	6	Morton Thiokol	7.5	14
8	Chesebrough-Pond's	746.0	15	Morton Thiokol	34.8	14	Rohm & Haas	7.3	9
9	Hercules	613.8	8	Hercules	33.3	5	PPG Industries	7.1	13
10	National Distillers	557.5	9	Monsanto	31.0	2	Petrolite	6.9	5

. . . and for the first nine months of 1985

Sales				Earnings[a]			Profitability		
Rank 1985		$ Millions	Rank 1984		$ Millions	Rank 1984		Earnings as % of sales	Rank 1984
1	Dow Chemical	$8628.0	1	Dow Chemical	$372.0	2	International Flavors	14.5%	1
2	Union Carbide	6684.0	2	PPG Industries	243.7	4	Freeport-McMoRan	11.1	4
3	W. R. Grace	5246.9	4	Monsanto	242.0	1	Nalco Chemical	11.0	2
4	Monsanto	4992.0	3	Union Carbide	214.0	3	Ethyl	8.5	12
5	PPG Industries	3250.0	5	Celanese	128.0	9	Petrolite	8.2	6
6	American Cyanamid	2646.0	6	Rohm & Haas	116.5	6	Air Products	8.0	8
7	Celanese	2286.0	7	Air Products	111.4	10	Loctite	7.8	3
8	Chesebrough-Pond's	2010.0	17	Hercules	111.1	5	PPG Industries	7.5	13
9	Hercules	1951.0	8	American Cyanamid	104.2	7	Rohm & Haas	7.4	5
10	National Distillers	1639.9	9	W. R. Grace	102.2	8	Morton Thiokol	6.7	16

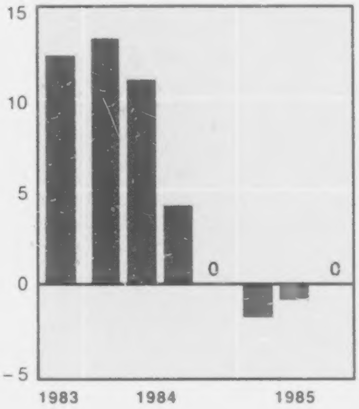
a After taxes. **Note:** Based on 30 companies listed on page 12.

Chemical industry 1985 third-quarter results

- Sales were flat
- Earnings fell 19%
- Profit margins were 3.9%
- Production was up 3.4%
- Prices rose just 0.6%

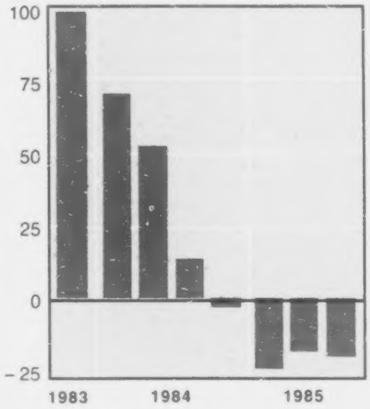
Sales

% change from year-earlier quarter



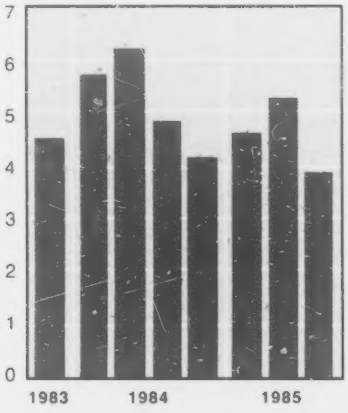
Earnings

% change from year-earlier quarter



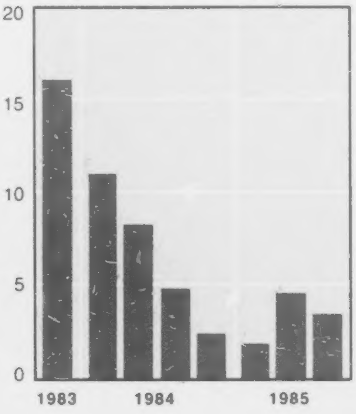
Profit margins

After-tax earnings as % of sales



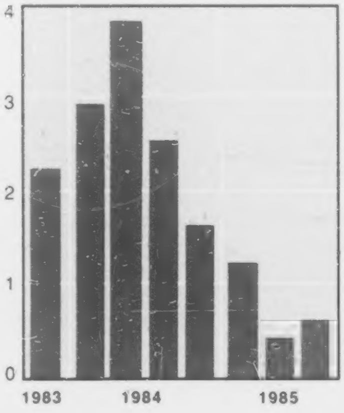
Production

% change from year-earlier quarter



Prices

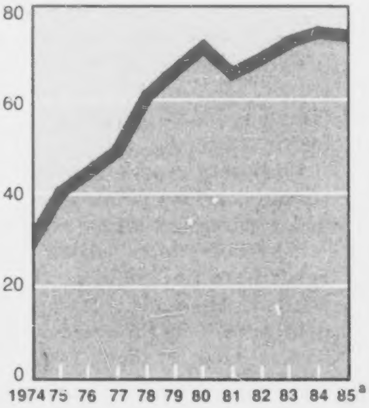
% change from year-earlier quarter



Sales in 1985 will fall 1%, and earnings will decline 17%, lowering profit margins considerably

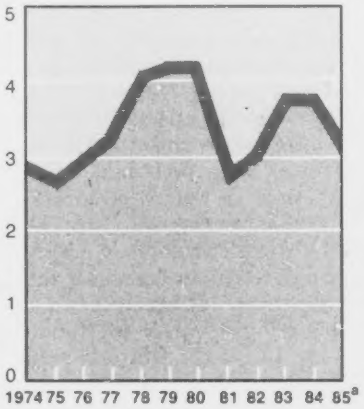
Annual sales

$ Billions



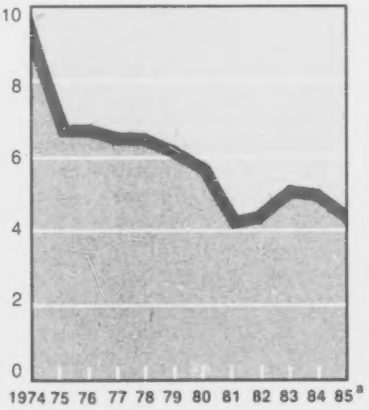
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



[a] C&EN estimates. **Note:** All sales, earnings, and profit-margin data are based on combined results of the 30 companies listed on page 12.

Composite earnings for chemical producers fell 19% in third quarter

	THIRD-QUARTER 1985						NINE-MONTHS 1985			
	Sales	Earnings[a]	Change from 1984		Profit margin[b]		Sales	Earnings[a]	Change from 1984	
	($ millions)		Sales	Earnings	1985	1984	($ millions)		Sales	Earnings[a]
Air Products[c]	$ 476.4	$ 38.1	14%	20%	8.0%	7.6%	$ 1,394.1	$ 111.4	6%	5%
American Cyanamid[c]	852.3	29.3	−1	−23	3.4	4.4	2,646.0	104.2	0	−27
Celanese[c]	758.0	47.0	−6	24	6.2	4.7	2,286.0	128.0	−9	−1
Chemed	96.9	5.2	9	15	5.4	5.1	278.5	17.5	9	63
Chesebrough-Pond's[c]	746.0	21.7	82	−32	2.9	7.8	2,010.0	60.4	82	0
Crompton & Knowles	56.6	1.8	3	1	3.1	3.1	174.0	5.3	−2	−11
Dow Chemical[c]	2,873.0	107.0	2	18	3.7	3.2	8,628.0	372.0	−1	−6
Essex Chemical	46.1	1.4	5	−37	3.1	5.2	150.4	7.3	10	−9
Ethyl	386.0	35.1	−9	−1	9.1	8.4	1,167.7	99.2	−9	4
First Mississippi	65.4	−0.3	−1	def	def	5.7	208.4	9.5	−7	−44
Freeport-McMoRan	161.5	17.8	−21	−17	11.0	10.5	567.1	63.1	−9	−5
H. B. Fuller	117.0	3.9	2	12	3.3	3.0	341.3	9.1	1	−5
W. R. Grace[c]	1,734.3	24.8	3	−29	1.4	2.1	5,246.9	102.2	5	−28
Hercules[c]	613.8	33.3	−9	−40	5.4	8.3	1,951.0	111.1	0	−27
International Flavors	127.6	18.2	8	8	14.3	14.2	378.7	55.1	2	−3
International Minerals[c]	315.1	4.1	−15	−87	1.3	8.4	1,194.0	51.9	−3	−37
Loctite	60.8	4.7	3	−22	7.8	10.3	174.7	13.6	−6	−33
Lubrizol	201.4	11.5	−2	−24	5.7	7.4	701.9	46.8	10	−13
Monsanto[c]	1,741.0	31.0	9	−60	1.8	4.9	4,992.0	242.0	−3	−39
Morton Thiokol[c]	460.5	34.8	5	14	7.5	6.9	1,408.2	94.8	3	22
Nalco Chemical	167.2	18.4	3	−3	11.0	11.8	497.6	54.8	0	−2
National Distillers[c]	557.5	17.9	5	88	3.2	1.8	1,639.9	42.4	−1	−30
Olin[c]	427.1	5.5	−1	−58	1.3	3.0	1,360.5	31.3	−1	−52
Pennwalt	246.2	−14.7	1	def	def	5.1	755.0	5.0	2	−85
Petrolite	74.4	5.1	−2	−24	6.9	8.9	228.8	18.7	5	0
PPG Industries[c]	1,040.0	73.9	−5	−4	7.1	7.0	3,250.0	243.7	2	3
Reichhold Chemicals	208.6	0.7	6	−89	0.3	3.2	628.9	5.2	1	−74
Rohm & Haas[c]	474.1	34.8	−2	−10	7.3	8.0	1,580.5	116.5	0	−21
Union Carbide[c]	2,254.0	58.0	−4	−25	2.6	3.3	6,684.0	214.0	−6	−28
Witco Chemical	366.6	14.9	−2	−7	4.1	4.3	1,101.1	40.6	−2	−13
Total 15 largest companies	**$14,577.2**	**$539.5**	**0%**	**−16%**	**3.7%**	**4.4%**	**$44,261.1**	**$1965.5**	**−1%**	**−19%**
Second 15 companies	**$ 2,382.4**	**$123.9**	**−2%**	**−28%**	**5.2%**	**7.0%**	**$ 7,353.8**	**$ 450.8**	**−1%**	**−13%**
GRAND TOTAL	**$16,959.6**	**$663.4**	**0%**	**−19%**	**3.9%**	**4.8%**	**$51,614.9**	**$2416.3**	**−1%**	**−18%**

a Excludes all significant extraordinary and nonrecurring items. b After-tax income as a percentage of sales. c One of 15 largest firms. **def** = deficit.

creased 5% on a sales decline of 5%, compared to the year-earlier period.

Although showing some signs of softening, the still-mighty dollar combined with the steady increase of chemical production overseas has had the effect of swelling the volume of imports and reducing markets for exports (down 1% in August from a year earlier, despite a slight overall improvement in the chemical trade balance that month).

At the same time, the greater quantity of imports, penetration in U.S. markets of which has been aided by the dollar's high value, has tended to disrupt the efforts of U.S. chemical producers to raise prices. In addition, continued low feedstock prices nourish downstream buyers' expectations of pass-along savings, maintaining what has become a long-lived buyer's market in petrochemicals. "There's no psychology for chemical price increases," the president of a large chemical company remarked in a recent conversation.

In their comments on the quarter's performance, several chemical company chief executives note the deleterious impact of the dollar's value on sales, although they see hope in suggestions that the U.S. currency's surge has peaked. "As we move into the fourth quarter and prepare to enter 1986, we are encouraged by the fact that the U.S. dollar has weakened since last spring," says Richard J. Mahoney, president and chief executive officer of Monsanto, net income for which fell 60% in the third quarter.

Weakness in several major downstream markets continued to hold down sales. The worst effects were felt by companies selling into the agriculture and semiconductor industries. The reeling farm economy continues to be hobbled by the financial woes of many farmers, and the semiconductor business, upset by overcapacity and sharp competition, has been marked all this year by widespread and severe employ-

NINE-MONTHS 1985		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1984		Profit margin	
1985	1984	Sales	Earnings	1985	1984
8.0%	8.1%	5%	2%	7.8%	8.1%
3.9	5.4	−1	−24	4.3	5.6
5.6	5.2	−7	−12	5.1	5.4
6.3	4.2	10	−13	4.6	5.9
3.0	5.5	0	−54	2.4	5.1
3.0	3.3	−4	−5	3.2	3.2
4.3	4.5	−3	−9	3.9	4.1
4.9	5.9	4	27	5.4	4.4
8.5	7.4	−11	11	8.9	7.2
4.5	7.6	−2	−25	5.2	6.8
11.1	10.7	−5	−1	11.7	11.2
2.7	2.8	1	−4	2.8	3.0
1.9	2.8	6	−34	1.7	2.7
5.7	7.8	−1	−25	5.8	7.7
14.5	15.2	3	−1	14.0	14.5
4.3	6.8	−1	−36	4.6	7.1
7.8	10.9	−4	−15	9.6	10.9
6.7	8.4	8	−7	6.9	7.9
4.8	7.8	−3	−41	4.3	7.0
6.7	5.7	1	−4	6.7	7.0
11.0	11.2	−4	−5	10.8	10.9
2.6	3.7	−12	−32	2.4	3.2
2.3	4.8	−3	−45	2.4	4.3
0.7	4.5	2	−58	2.1	5.0
8.2	8.6	5	10	8.5	8.1
7.5	7.4	1	3	7.4	7.3
0.8	3.2	0	−56	1.4	3.1
7.4	9.3	1	−21	7.0	8.9
3.2	4.2	−4	−26	3.0	3.9
3.7	4.2	−1	−11	3.7	4.2
4.4%	**5.4%**	**−2%**	**−22%**	**4.1%**	**5.2%**
6.1%	**7.0%**	**−1%**	**−8%**	**6.4%**	**6.9%**
4.7%	**5.7%**	**−2%**	**−19%**	**4.5%**	**5.4%**

ment reductions and production cutbacks.

Representative of the problems facing chemical producers is First Mississippi Corp., which reported a $258,000 loss in the third quarter. The primary cause of the deficit, the company says, was lower prices for ammonia, urea, oil, and natural gas. Selling into those weak markets was trouble enough, but hurricanes, turnaround maintenance, and other unusual expenses compounded the difficulties. As a result, First Mississippi's industrial chemicals segment posted a 71% decline in pretax operating profits, and its oil and gas unit, battling a 20% decline in average selling prices, turned in a 77% drop in operating profits. Worst was the fertilizer business, for which a 25% decrease in average selling prices led to a loss on operations.

The ailing fertilizer business's depredations on companies' third-quarter earnings were widespread. A chief contributor to American Cyanamid's 23% decline in net income, for instance, was a loss by the firm's agricultural group, primarily the result of the fertilizer slump. W. R. Grace blames its 29% earnings decrease on fertilizer; its agricultural chemical unit lost $4.8 million after taxes, compared to a $2.4 million operating profit in the year-earlier quarter.

The farm recession also hurt the performance of pesticides and other agricultural chemicals badly. For instance, Chesebrough-Pond's agricultural products division (part of this year's Stauffer Chemical acquisition) reported lower sales for crop protection chemicals and hybrid corn, sorghum, and sunflower seed.

For Monsanto, whose agricultural products accounted for a whopping 88% of operating profits over the first nine months of the year, the failure of farmers to buy as much Roundup and Lasso pesticides and other star products as before contributed to a 60% drop in third-quarter net income. During the quarter, agricultural product sales fell 18% and pretax income plummeted 45%. Such poor performance by the company's key business segment meant there was little to compensate for a $22 million pretax loss by the electronic materials unit along with pretax profit declines of 36% for polymer products, 13% for fibers and intermediates, and 6% for industrial chemicals. It also left little to cover the deficits recorded by the company's increasingly expensive biological sciences unit, which, with its gargantuan appetite for R&D funds, lost $33 million in the quarter and $87 million during the first nine months of the year. In 1984, by comparison, the unit's deficit over nine months was $61 million before taxes.

For Rohm & Haas, net income dropped 10% in the third quarter. "Operating losses in our agricultural and electronic chemicals businesses and higher interest expenses were the primary causes of the lower third-quarter earnings," says Vincent L. Gregory Jr., chairman of the company. The poorer results, which had been expected (C&EN, Sept. 23, page 6), were due in large part to lower-than-anticipated late season sales of the company's Blazer herbicide for soybeans and $4.1 million in startup costs for its hybrid seed wheat business. Consequently, Rohm & Haas' agricultural chemicals segment reported a net

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 38 oil and diversified companies, each with more than $200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 40% of its sales in chemicals, and its chemical operations must be the largest single portion of the company operations. That is why Du Pont, for example, is not included as a basic chemical producer but rather as a diversified manufacturer.

In referring to chemical sales, C&EN means sales of those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Earnings for energy and diversified firms also declined

	% chemical sales	THIRD-QUARTER 1985						NINE-MONTHS 1985					
		Sales	Earnings[a]	Change from 1984		Profit margin[b]		Sales	Earnings[a]	Change from 1984		Profit margin[b]	
		($ millions)		Sales	Earnings	1985	1984	($ millions)		Sales	Earnings	1985	1984
OIL AND GAS COMPANIES													
American Petrofina	15%	$ 599.3	$ 10.2	6%	462%	1.7%	0.3%	$ 1,759.8	$ 20.4	9%	−27%	1.2%	1.7%
Amoco	10	7,200.0	490.0	1	−18	6.8	8.5	21,500.0	1563.0	−2	−9	7.3	7.8
Atlantic Richfield	10	5,502.0	317.0	−9	110	5.8	2.5	17,040.0	1178.0	−8	12	6.9	5.6
Chevron	4	10,300.0	245.0	−28	−28	2.4	2.4	34,600.0	946.0	1	−14	2.7	3.2
Diamond Shamrock	21	1,053.6	52.8	−7	−14	5.0	5.4	3,038.4	157.8	−11	−15	5.2	5.4
Exxon	7	22,298.0	1130.0	−5	−11	5.1	5.4	68,531.0	3200.0	−6	−22	4.7	5.6
HNG/Internorth	5	2,851.7	38.9	67	10	1.4	2.1	8,027.0	165.2	86	−22	2.1	4.9
Kerr-McGee	13	789.6	39.8	−6	84	5.0	2.6	2,445.0	108.9	−7	9	4.5	3.8
Mobil	4	14,400.0	392.0	−4	65	2.7	1.6	44,200.0	1123.0	−2	14	2.5	2.2
Occidental Petroleum	7	3,383.1	200.8	−14	31	5.9	3.9	10,758.5	421.3	−7	10	3.9	3.3
Phillips Petroleum	15	4,000.0	123.0	7	−43	3.1	5.8	12,000.0	336.0	2	−48	2.8	5.5
Shell Oil	16	5,424.0	389.0	−3	−13	7.2	8.0	15,774.0	1022.0	−4	−14	6.5	7.3
Standard Oil (Ohio)	5	3,440.0	346.0	19	−4	10.1	12.4	10,130.0	1079.0	12	−10	10.7	13.2
Sun Co.	3	3,330.0	115.0	−3	−6	3.5	3.6	10,680.0	388.0	−8	−3	3.6	3.5
Tenneco	7	3,773.0	105.0	12	−17	2.8	3.7	11,254.0	332.0	2	−34	3.0	4.5
Texaco	2	11,300.0	301.0	−7	18	2.7	2.1	35,000.0	785.0	−3	−3	2.2	2.3
Unocal	10	3,040.0	67.9	5	−63	2.2	6.3	8,720.0	605.8	2	11	6.9	6.4
DIVERSIFIED MANUFACTURERS													
Allied-Signal	15	1933.0	95.0	−25	−25	4.9	4.9	7,467.0	381.0	−8	−2	5.1	4.8
Aluminum Co. of America	4	1,282.2	57.1	−11	−5	4.5	4.2	3,980.1	104.3	−10	−61	2.6	6.2
Borden	28	1,199.6	51.3	5	13	4.3	4.0	3,469.6	132.3	1	2	3.8	3.8
Borg-Warner	21	963.6	53.1	2	1	5.5	5.6	2,935.7	146.7	0	−2	5.0	5.1
Du Pont	32	8,529.0	285.0	−2	−10	3.3	3.6	25,320.0	789.0	−6	−30	3.1	4.2
Engelhard	23	533.4	9.5	−14	−47	1.8	2.9	1,588.4	31.5	−15	−39	2.0	2.8
FMC	39	767.8	59.0	3	−6	7.7	8.4	2,404.9	157.5	−3	−11	6.5	7.1
General Electric	7	6,520.0	575.0	−3	2	8.8	8.4	19,560.0	1676.0	−2	3	8.6	8.2
Georgia-Pacific	10	1,752.0	58.0	−0	−28	3.3	4.6	5,126.0	174.0	4	−8	3.4	3.9
B. F. Goodrich	35	834.9	0.8	−2	−97	0.1	2.9	2,400.0	15.0	−4	−78	0.6	2.7
Kaiser Aluminum	18	526.4	−14.2	−4	def	def	def	1,516.1	−43.6	−9	def	def	2.5
Koppers	45	518.4	20.1	−1	−22	3.9	4.9	1,358.3	15.6	2	−53	1.1	2.5
Eli Lilly	23	787.9	122.1	11	9	15.5	15.7	2,453.6	393.1	5	6	16.0	16.0
3M	15	2,023.0	173.0	2	−13	8.6	9.9	5,883.0	516.0	1	−9	8.8	9.7
Merck	17	855.8	136.1	0	13	15.9	14.1	2,589.5	405.5	0	7	15.7	14.5
NL Industries	35	360.4	5.0	6	−22	1.4	1.9	1,045.9	16.3	4	44	1.6	1.1
Pfizer	10	1,012.8	155.5	2	16	15.4	13.5	2,966.6	440.4	2	16	14.8	13.1
Tyler	33	233.6	5.9	−5	−40	2.5	4.0	693.5	14.7	−2	−34	2.1	3.2
Upjohn	13	474.7	45.7	9	49	9.6	7.1	1,494.3	152.9	4	5	10.2	10.1
U.S. Steel	6	5,000.0	61.0	6	−3	1.2	1.3	14,600.0	94.0	1	−73	0.6	2.4
Vulcan Materials	26	274.1	28.7	64	0	10.5	17.2	742.2	59.3	2	−3	8.0	8.4

a From continuing operations excluding nonrecurring and extraordinary items. b Earnings as a percentage of sales. def = deficit.

loss of $8.4 million on a one-third sales decline. Over nine months, the unit's earnings were down 55% on an 8% sales decrease.

There were some bright spots in the industry, though. Coatings, for example, did well in the quarter. PPG Industries, whose overall net income declined 4%, posted sales gains for automotive finishes and industrial coatings. Morton Thiokol, which reported a 14% rise in earnings, says it had strong growth in sales of customized performance coatings and powder coatings.

Industrial gases also performed fairly well in the third quarter. Union Carbide, preoccupied with its massive restructuring program, managed a pretax gain of 3% on industrial gases on a 2% sales increase. And Air Products' pretax profit on industrial gases rose 18% on a sales rise of 10%.

The smaller half of the 30 largest chemical companies were particularly hard hit in the third quarter, with composite earnings down 28% from third-quarter 1984, compared with 16% for the 15 biggest firms. Net income at Petrolite, for instance, fell 24% in the quarter (which ended for Petrolite on July 31). Although sales of oil field chemicals, the company's chief product line, were up for the first nine months of the company's fiscal year, they were lower than expected on an international basis in the quarter. At Nalco Chemical, water treatment and process-related businesses were stable, chief executive W. H. Clark Jr. says, but oil field chemicals were damaging. The result: a 3% decline in net income. The same problem helped lower the earnings of NL Industries, a diversified firm, 22% in the third quarter. Continued weakness in domestic drilling activity—the active rig count was 20% lower than a year earlier—caused a $3.2 million operating loss in NL's petroleum services segment.

Loctite's net income fell 22% compared to the year-earlier quarter. Reichhold Chemicals reported an 89% decline in earnings. And Witco Chemical earnings dropped 7% in the quarter.

Diversified firms with substantial chemical operations also had their problems in the third quarter. For example, B. F. Goodrich's net income plunged 97% from the year-earlier period. The chief culprit was tires, the company's largest single segment, operating income of which fell 53%. But little help came from the second largest unit, polyvinyl chloride. PVC operating income rose slightly in the third quarter, mostly thanks to cost-cutting measures, but over the first nine months, profits were only half of what they were at the same point a year ago.

Kaiser Aluminum & Chemical posted a $14.2 million loss in the quarter; over the first nine months of this year, the company lost $43.6 million. Most of the deficit stems from the continuing aluminum slump, but the company's industrial chemicals business also lost money. Poor markets for the division's basic chemical and oil-related catalyst lines, compounded by costs arising from now-resolved labor difficulties at several plants, were the cause.

FMC's sales of performance chemicals fell 8% in the third quarter to $119 million, reducing profitability. As at so many other firms, the agriculture market was blamed. Sales of crop protection chemicals fell, in this case, FMC says, because of a less severe infestation by corn borers than in 1984. Sales of the company's industrial chemicals increased 10%, but that was chiefly because of the July acquisition of Lithium Corp. of America. Nonetheless, the segment's profits dropped because of lower phosphate sales and gold production. Overall, FMC's net income declined 6% in the third quarter on a sales gain of 3%.

Du Pont's net income declined, too. In the third quarter it dropped 10%, and during the first nine months of the year, earnings declined 30% from the similar period last year. Year-to-date, Du Pont's nonenergy businesses have performed poorly. After-tax operating income, excluding a special gain, fell throughout those segments: biomedical products, down 37%; industrial and consumer products, down 31%; fibers, down 35%; polymer products, down 37%; and agricultural and industrial chemicals, down 57%. □

Petrochemicals fared poorly in third quarter

Oil and gas companies, already beleaguered by the continuing energy slump, received no help from their petrochemical operations in the third quarter of 1985. For a group of seven energy companies that break out after-tax earnings by product segment, net income from chemicals dropped a composite 23% in the period compared with the same three-month period a year before.

The bulk of the oil and gas companies' chemical activities tends to be in petrochemicals, so segment results provide a good indication of how petrochemicals in particular are performing.

At Exxon, earnings from worldwide chemical operations fell 36% to $59 million in the quarter. The company explains that, although sales volumes increased, lower margins, higher costs, and excess capacity led to the decrease in net income. Over the first nine months of the year, the decline was worse; the net income of $176 million from chemicals was 49% less than income during last year's first nine months.

Amoco also notes that its higher sales volume failed to offset the adverse effects of lower margins. The result: a 4% decline in net earnings on chemicals to $51 million. On a positive note, the company says it improved capacity utilization of its chemical and polymer facilities to 88% from 77% in third-quarter 1985.

Shell, which recorded a 62% drop in chemical earnings, gives similar reasons for the decline. "The major factor in the declines was continuing lower margins in base chemicals, primarily olefins," says John F. Bookout, president. "Current prices for ethylene are the lowest in recent years. Other factors included lower agricultural chemical volumes and higher operating expenses."

Mobil's third-quarter chemical earnings improved, thanks mostly to the performance of its Saudi Arabian joint venture. Over nine months, however, net income from chemicals was down 39%.

Standard Oil (Ohio) reported a pretax increase in chemicals operating income. The gain was partly from better results by the company's nitrogen chemicals business. The other reason for improvement was that the company sold its money-losing agricultural products business in the first quarter of the year.

AFTER-TAX EARNINGS ON CHEMICAL OPERATIONS

	Third quarter			First nine months		
$ Millions	1985	1984	% change	1985	1984	% change
Amoco	$51	$53	−4%	$150	$169	−11%
Atlantic Richfield	30	35	−14	63	82	−23
Chevron	−2	1	def	33	48	−31
Exxon	59	92	−36	176	346	−49
Mobil	24	15	60	35	57	−39
Shell	14	37	−62	63	116	−46
Texaco	4	4	0	7	13	−46

def = deficit.

Organics Lead Canadian Chemical Upturn

After looking at their bottom lines, some Canadian chemical companies may be hard-pressed to agree, but the chemical industry in Canada is, in fact, perking along so far this year in somewhat better shape than last year. Of those chemicals charted by Statistics Canada, more scored production increases than declines through the first seven months of the year.

Much of the strength lies in ethylene and its polymer derivatives. Inorganics, however, have been generally weak across the board.

Increases in polyethylene and polyvinyl chloride output have supported a 16% jump in Canadian ethylene production through the first seven months. The outstanding performer has been low-density polyethylene. Output through July jumped a whopping 50% (411,000 metric tons compared with 274,000 metric tons in the first seven months of 1984).

The primary reason behind this meteoric rise in LDPE production, of course, is Novacor Chemicals' new 270,000 metric ton-per-year linear low-density polyethylene plant, which came on stream at Joffre, Alta., in mid-1984. Although higher demand in the domestic market absorbed some of the LDPE flood, most of it moved into the export market. Through mid-year, Canadian polyethylene exports (both low- and high-density) were up 160% over last year.

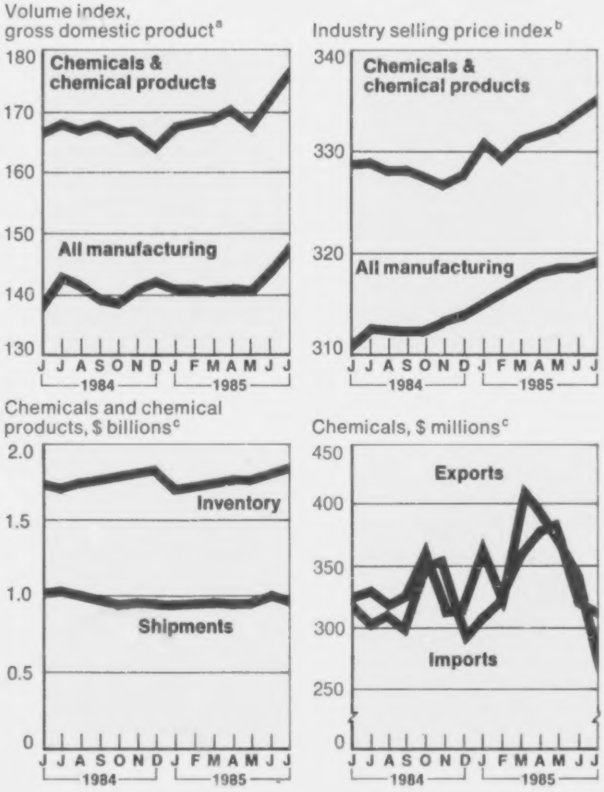
Now, Canadian polyethylene producers will have to make room for Dow Chemical Canada's new plant at Fort Saskatchewan, Alta. That 120,000 metric-ton unit is designed primarily as a LLDPE plant, but it also can produce HDPE, much of which probably will be earmarked for the U.S. market.

Although polyethylene export volumes have been up, profits on those sales have been nothing to brag about. Union Carbide Canada chairman W. Norman Kissick blames, in large part, a continuing and severe cost-price squeeze in polyethylene for a nine-month operating loss of $4.9 million on sales of $348 million. That's before the company took a $75 million extraordinary loss related to its decision to divest its polyethylene business, a plant in Moore Township, near Sarnia, Ont.

These polyethylene developments have obscured an impressive performance by PVC. Through the first seven months, Canadian PVC output was up 12% to 169,000 metric tons. Exports to the U.S. were running 30% higher than last year. Meanwhile, Canadian demand for PVC was also up, thanks primarily to improved housing starts. Canadian housing is having its best year since 1981, and that is reflected in higher PVC consumption for pipe and siding.

The strong housing market is having a beneficial impact on other segments of the chemical industry as well. Paints and varnishes, adhesives, and other plastics products are benefiting from the robust market.

Earl Anderson, New York



a Seasonally adjusted, 1971 = 100. **b** 1971 = 100. **c** For 1984, \$1.00 = \$1.31 Canadian; for 1985, \$1.00 = \$1.36 Canadian. **Source:** Statistics Canada

Inorganic chemical production weak

Production, thousands of metric tons	1984	First seven months 1985	1984	% change 1984–85
ORGANICS				
Ethylene	1464	966	831	16.2%
Propylene	665	363	398	−8.7
Benzene	557	375	333	12.6
Toluene	430	265	240	10.5
Xylene	417	237	235	0.9
PLASTICS				
Polyethylene, low density	529	411	274	50.4
Polyethylene, high density	227	135	129	4.1
Polyvinyl chloride	252	169	150	12.4
INORGANICS				
Hydrochloric acid	161	91	94	−3.3
Nitric acid	1100	664	658	0.8
Phosphoric acid[a]	691	381	428	−10.9
Sulfuric acid	4053	2310	2424	−4.7
Ammonia, anhydrous	3493	2029	2111	−3.9
Ammonium phosphate	1383	797	839	−5.0
Chlorine	1424	826	816	1.2
Sodium hydroxide	1575	915	907	0.9

a 100% P_2O_5. **Source:** Statistics Canada

Money Bills for Federal Agencies Continue To Stall in Congress

Both House and Senate have passed versions of fiscal 1986 bills, but most have been derailed in conference by a balanced budget amendment

Senate allows more for R&D than House—but not much

$ Millions	1986 Senate	1986 House	1986 Request	1985
NASA	**$ 7,630.0**	**$ 7,666.0**	**$ 7,886.0**	**$ 7,491.4**
Space flight control and data communications	3,375.0	3,402.9	3,509.9	3,601.8
R&D	2,760.1	2,756.8	2,881.8	2,422.6
Management activities	1,354.9	1,367.0	1,345.0	1,317.0
Facilities	139.7	139.3	149.3	150.0
HHS	**5,652.9**	**5,667.5**	**5,040.9**	**5,327.5**
NIH	5,228.1	5,247.8	4,631.8	4,912.7
FDA	424.8	419.7	409.1	414.8
Energy	**4,397.4**	**4,170.9**	**4,155.0**	**4,207.1**
Energy supply R&D	2,066.9	1,928.6	1,952.1	1,999.0
Nuclear	631.9	607.6	657.6	623.0
Supporting research and technical analysis	502.3	514.0	480.8	477.8
Magnetic fusion	382.0	385.0	390.0	437.0
Environment	330.7	229.7	227.7	230.5
Solar	161.7	147.0	148.0	178.0
Electric energy systems and storage	30.1	30.1	26.1	40.1
Geothermal	27.2	26.2	25.2	31.8
Weapons R&D	**1,291.6**	**1,072.4**	**1,211.6**	**1,027.3**
General science and research	**679.4**	**685.5**	**685.4**	**730.0**
Fossil R&D	**292.2**	**299.5**	**160.5**	**274.9**
Conservation R&D	**167.5**	**173.9**	**142.7**	**156.0**
NSF	**1,521.6**	**1,522.9**	**1,568.4**	**1,499.0**
Research and related activities	1,348.0	1,347.2	1,397.7	1,301.9
Antarctic programs	113.8	115.1	120.1	110.1
Science education activities	59.8	60.6	50.6	87.0
EPA	**1,478.2**	**1,491.2**	**1,362.6**	**1,309.8**
Salaries and expenses[a]	680.8	690.2	654.7	656.3
Abatement, control, and compliance	571.2	577.6	495.5	460.5
R&D	226.2	223.4	212.4	193.0
Commerce	**1,346.1**	**1,329.9**	**1,139.0**	**1,337.3**
NOAA	1,131.7	1,121.2	934.3	1,113.1
NBS	125.9	124.0	120.0	124.0
PTO	88.5	84.7	84.7	100.2
USDA	**928.1**	**905.5**	**849.8**	**912.4**
Agricultural Research Service	501.0	492.8	483.3	494.1
Cooperative State Research Service	290.4	276.4	251.2	285.8
Forest Service Research	125.4	125.0	104.2	121.0
National Agricultural Library	11.3	11.3	11.1	11.5
TOTAL	**$22,954.3**	**$22,753.9**	**$22,001.7**	**$22,084.5**

[a] Includes in-house research funding.

The current fiscal year, 1986, began a month and a half ago, but by press time Congress had managed to enact only two of the 13 appropriation bills that set actual funding levels for the federal agencies. Not that it hasn't been trying; the House has passed 11 and the Senate 10 of the appropriations bills.

But conference action to reconcile differences between each branch's version of the bills—usually a simple and quite fast procedure—has been derailed by a balanced budget amendment attached to a routine measure raising the public debt limit.

It's hard to discern a trend for R&D funding in what has happened so far. The House disagreed with the Administration over the proper funding level for many programs, sometimes approving more money, sometimes less than was requested (C&EN, Aug. 5, page 17). And the Senate, though generally agreeing with the House on which requests should be increased or decreased, doesn't agree on how much they should be changed.

For example, the Administration wanted to cut funding for the National Institutes of Health 6%, or $281 million, to $4.6 billion. The House opted for a $335 million increase, the Senate $315 million. Overall, the Senate provided $2.1 billion to support at least 12,662 noncompeting research grants; $960 million to support at least 6000 new and competing research grants; $500 million to support 533 research centers at their historical levels; and $597 million for intramural research within NIH. The Senate accepted an Administration proposal that would freeze every NIH grantee's indirect cost rate at the rate in effect on Dec. 31, 1984. The House rejected the proposal.

Both chambers reduced the Administration's $2.9 billion budget request for the National Aeronautics & Space Administration's R&D programs, the House by $125 million, the Senate by $122 million. The final Senate figure would have been $30 million higher except that during floor consideration of the HUD-Independent Agencies Appropriation bill, an amendment was offered and accepted calling for a 1.1% across-the-board reduction in all funding contained in the bill.

That amendment also had an adverse effect on the National Science Foundation. The Senate Appropriations Committee had approved $1.4 billion for the foundation's research and related activities in fiscal 1986, a figure that was already $37 million below the budget request, although $16 million over the House allowance. After the across-the-board decrease, the Senate figure was just $1 million more than the House's $1.35 billion. NSF says that for it to come as close as possible to its original budget request of $1.6 billion, conferees on the bill are going to have to delete the across-the-board reduction, accept the House figures for science education and for the Antarctic program, and accept the Senate's original figure for research and related activities.

Even with the 1.1% reduction, the Senate approved $226 million for extramural R&D programs for the Environmental Protection Agency. That figure is 1% over the House allowance, 6% over the budget request, and 17% over fiscal 1985 funding. The Senate added $2 million to the budget request for additional groundwater and hazardous waste research, $1.5 million for toxic sediment removal studies in the Great Lakes, and $2.9 million for air pollution studies. One is an epidemiological study that can detect significant changes in mortality or morbidity caused by pollutants regulated by current ambient air standards.

The Senate was more generous than either the House or the Administration when it came to funding Department of Agriculture research programs. It provided a total of $928 million, 3% more than the House allowed, 9% more than the Administration requested, and 2% more than 1985 funding. The same can be said for the Department of Commerce research programs. The total Senate figure of $1.3 billion is 1% more than the House allowance, 18% more than the budget request, and just about equal to 1985 funding.

The House, which by law must act first on appropriation bills, passed the Department of Defense appropriation bill on Oct. 30. It contains $33.1 billion for defense R&D programs in fiscal 1986. That figure represents a 6% increase over fiscal 1985 funding, quite a bit less than the requested 26% increase.

In past years, the usual practice has been for the conferees on any one appropriation bill to average the House and Senate numbers and come up with a final total. However, the past may not be any guide this year.

For example, the Administration requested $1.2 billion for the Department of Energy's weapons R&D program in fiscal 1986. The House allowed $1.1 billion, the Senate $1.3 billion. The final figure was less than either of those. The same thing happened in reverse to the budget for DOE's supporting research and technical analysis program, which among other things supports chemical sciences and materials sciences. The Administration requested $481 million for the program. The House allowed $514 million, the Senate $502 million. Yet the final conference figure was $518 million. That includes $96 million for chemical sciences, 2% more than both the request and 1985 funding. Funding for materials sciences is set at close to $197 million, 8% more than requested and 2% more than 1985. The materials funding includes $8 million for the national center for chemical research and $11 million for the center for advanced materials research.

Janice Long, Washington

Federal Alert—new regulations

This listing highlights regulations as published in the Federal Register *from Oct. 7 to Nov. 1. Complete information is available on the appropriate page number.*

PROPOSED

Consumer Product Safety Commission—Publishes semiannual list of regulations expected over next 12 months, including action on urea-formaldehyde resins; comments on agenda by Dec. 31 (Oct. 29, page 44882).

Environmental Protection Agency—Begins comprehensive study of methylene chloride to determine need for regulatory controls to reduce exposures; comments by Dec. 16 (Oct. 17, page 42037).

Produces semiannual agenda of nearly 300 regulations agency expects to complete or propose over next year (Oct 29, page 44644).

Labor Department—Lists regulatory agenda for next 12 months including upcoming rules on hazardous chemicals from Occupational Safety & Health Administration (Oct. 29, page 44302).

Nuclear Regulatory Commission—Updates semiannual list of regulations with all actions proposed or under consideration during next 12 months (Oct. 29, page 44992).

FINAL

Environmental Protection Agency—Lists chemical waste products from production of dinitrotoluene, toluenediamine, and toluene diisocyanate as hazardous and subject to special regulation; effective April 23, 1986 (Oct. 23, page 42936).

Occupational Safety & Health Administration—Amends ethylene oxide standard to exempt labels on pesticide products regulated by federal pesticide laws; effective Jan. 9, 1986 (Oct. 11, page 41491).

NOTICES

Environmental Protection Agency—Intends to list 1,3-butadiene as potential toxic air pollutant and may set emission standards; comments by Dec. 9 (Oct. 10, page 41466).

Publishes inventory of "open dumps," those operating waste sites that do not comply with Resource Conservation & Recovery Act criteria for solid waste disposal sites (Oct. 16, page 41952).

Begins special review action on pesticide carbofuran with intention to cancel registration because of bird toxicity; comments by Dec. 2 (Oct. 16, page 41938).

Occupational Safety & Health Administration—Plans to form panel of interested parties to negotiate proposed rule for occupational exposure to 4,4'-methylenedianiline (MDA); comments by Nov. 21 (Oct. 22, page 42789).

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Underwater mining enters new development phase
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BIOTECHNOLOGY

Commercial consolidation begins
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CHEMICAL & ENGINEERING
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News of the Week

- **Uniroyal Chemical, wholly owned subsidiary of Uniroyal Inc., is on the selling block.** **Page 4**
- **NIH okays field test of tobacco plant genetically engineered to be resistant to disease.** **Page 4**
- **Mary L. Good is ACS president-elect for 1986.** **Page 5**
- **UCSD neurosciences professor Robert Katzman receives first Achievement Award in Aging in Allied-Signal program.** **Page 6**
- **Genentech, Lubrizol, and Pfizer agree to produce vitamin C by two-step process involving genetically modified bacteria.** **Page 6**

Cover: Culture room in Damon Biotech's cell culture facility, which produces monoclonal antibody in 40-L reactors

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Business

Monsanto's restructuring program will affect plastics, chemicals, and ag chemicals businesses especially in company's drive to improve its profitability. **Page 13**

The U.S. uranium industry has fallen flat on its face, owing to low demand amd competition from cheap imports. **Page 15**

Oil-field chemicals market has declined significantly in the past few years with drop in drilling activity. **Page 16**

Government

High levels of radon in homes in some areas lead to EPA and state programs to monitor the radioactive gas. **Page 18**

Need for acid rain emission controls endorsed by American Public Power Association, a group that is made up of publicly owned utilities and is a member of the Acid Rain Roundtable. **Page 20**

Technology

Marine miners will emphasize science to improve their efforts to uncover marine minerals, to gain a better understanding of the oceans, and to develop tools for undersea mining. **Page 63**

International Fertilizer Development Center plays important role in increasing food supplies in developing countries. **Page 67**

Product Report

Character of the biotechnology industry is about to change: It will comprise some of today's biotech firms as well as established chemical and drug companies. **Page 25**

order of Lasso or Roundup." He indicates, however, the unlikelihood of coming up with the blockbuster type of product that these have been.

Further adding to Reding's problem of declining profitability is the suffering agricultural economy, which has caused farmers to cut back on planting and the resultant use of herbicides. "I just don't see the farm economy improving much in the next five years," he says.

To help counter the effect of this trend, Reding says agricultural chemical operations are being split into three profit centers—animal science, plant technology, and agricultural chemicals. And agricultural chemicals will be split into North American and foreign.

In R&D, Monsanto has mainly two focuses—plant technology and animal health. Its big hope in animal health products is its bovine growth hormone currently being tested. The hormone will not be used to make bigger cows as such, but rather to make milk production more efficient. In plant sciences, Monsanto currently has three programs—crop improvement, microbials, and wheat hybridization. It is the wheat program that Reding says will have the earliest payout, but even that will not be until late in the decade.

William Storck, New York

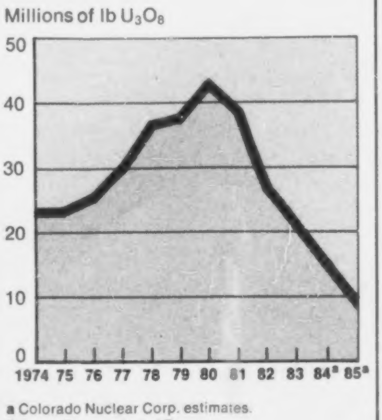
Uranium industry continues in doldrums

The U.S. uranium mining and milling industry is "nonviable." So says John S. Herrington, Secretary of Energy, who is required by law to determine the state of the industry's health.

But people in the industry didn't need an official pronouncement of nonviability to know that they were in big trouble. After years of heavy investments in the face of a declining market and sharply lower selling prices, the industry's bottom line gave it to them straight. Last year, the industry lost $205 million.

The big question now is why. Why did a promising domestic uranium industry fall flat on its face? Some experts are looking beyond the obvious—curtailed demand, low prices, cheap import competition, and huge inventories—to other, more subtle reasons. They are pointing their fingers, not only at the utilities that buy uranium to fuel their nuclear power plants, but at the public utility commissions (PUCs) that control the utilities.

U.S. uranium production plummets



a Colorado Nuclear Corp. estimates.
Source: Department of Energy

John W. LaFond, executive vice president of SWUCO Inc., insists that some of the most serious uncertainties facing uranium-buying utilities in the U.S. are the second guesses state PUCs make on their buying decisions. Concern over future PUC actions, which borders on paranoia at times, has driven many prospective buyers to insist on long-term arrangements with market-based or spot-based pricing. Such terms, or even the spot market itself, says LaFond, make utilities seem relatively safe from future PUC criticism, especially when ratemaking decisions are being made.

Prices related to the spot market may be safe for dealing with PUCs, says LaFond. But, he told a recent meeting of the Atomic Indusrial Forum in Santa Fe, N.M., they run contrary to rational marketing strategy. Such a strategy gives more consideration to the long-term requirements of both the buyer and the seller. These objectives, he adds, are mutually supportive. "There is nothing conflicting about them."

With few exceptions, U.S. uranium producers cannot meet the terms sought by today's U.S. uranium buyers. Thus, in trying to placate their PUCs, U.S. utilities are "fostering the demise of the U.S. uranium industry," LaFond says. This, he adds, leads necessarily to increasing reliance on foreign suppliers.

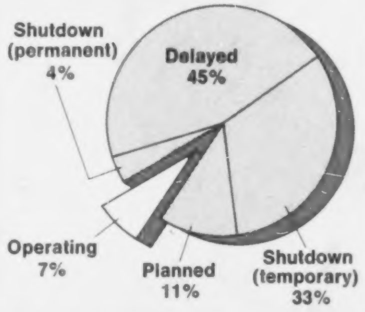
Even the PUCs, LaFond suggests, might not like such a situation if they were completely aware of the facts. The problem is that because of the PUC-utility adversarial relationship, the PUCs wouldn't believe the utilities if they explained it to them. Instead, he urges that domestic uranium producers themselves take their case directly to the PUCs.

Gunther Lurf agrees that most U.S. utilities would benefit over the long haul by long-term uranium contracts. But Lurf, who is president of NUKEM Inc., concedes that the way the uranium market has developed recently raises doubts about the advantage of signing these contracts.

Over the past two years, utilities have been able to buy even large volumes of uranium on the spot market for half the world average price set by long-term contracts. It's not surprising, then, that buyers are moving away from long-term contracts and into the spot market.

During the first nine months of the year, more than 13 million lb of uranium (as U_3O_8) was traded on the spot market, NUKEM records indicate. That's 20% of all the uranium produced in the western world. Traditionally, the spot market amounts to only 10%, says Lurf.

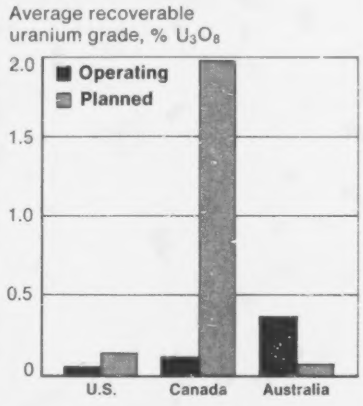
U.S. uranium reserves: not much operating



Total recoverable U.S. reserves = 1.062 biilion lb

Source: Rocky Mountain Energy Co.

Canadian uranium ore will be top grade



Source: Rocky Mountain Energy Co.

He, too, blames PUCs, which have forced some utilities to abandon long-term contracts, for contributing to the trend. In other countries, Lurf says, the emphasis on spot-market buying is very limited.

In the U.S., however, very few utilities have signed long-term contracts for uranium over the past several years. Indeed, some have canceled existing agreements. In 1980, almost 70% of utilities' 10-year forward uranium demand was covered by long-term contracts. This year, the figure is only 45%.

Such trends are leaving the long-term uranium requirements of U.S. utilities relatively "uncovered"; that is, not under contract. In the U.S., only four years' worth of supply is under long-term contract, Lurf says. European supply is contracted eight years ahead, whereas in Asia, buyers have contracted for 11 years of forward supply.

Looking ahead to 1995, Lurf estimates that U.S. utilities have covered only 13% of their demand through long-term contracts. Another 20% could come from existing or planned domestic production. But that still leaves two thirds of U.S. uranium requirements uncovered. Asia has more than 70% of its needs covered, and Europe has an excess supply. Lurf warns that, although spot market uranium may be cheaper than material under long-term contract today, that is not going to hold true in the long run.

Earl Anderson, New York

Drop in drilling hurts oil-field chemicals market

When it was conventional wisdom that the oil shortage and consequent price increases would go on forever, it was also accepted thinking that oil-field chemicals was the market to be in. But events in the past few years have proven that notion faulty, and oil-field chemicals have fallen on hard times as drilling activity declines. The consumption of oil-field chemicals is directly related to drilling activity, and two new studies point out how far that market has declined and where opportunities still exist.

U.S. drilling activity has dropped significantly over the past several years, with a concomitant drop in the market for all kinds of oil-field chemicals, notes a study by Frost & Sullivan, New York City-based consultants. On the other hand, there are still opportunities for marketers of oil-field chemicals in developing countries, particularly nonmembers of the Organization of Petroleum Exporting Countries, predicts a new survey by C. A. Houston & Associates of Mamaroneck, N.Y.

According to Frost & Sullivan, the rig count in the U.S. began dropping early in 1982, and although drilling activity spurted briefly in 1983, a further slowdown began last year. The result has been an oil-field chemical market that has shrunk from an estimated $1.43 billion in sales in 1981 to about $1.14 billion last year. The decline has affected both the companies that actually supply chemicals and services for drilling, cementing, stimulation, completion and production, and the hundreds of chemical and mineral producers who, in turn, supply them.

And though the study predicts a return to growth, it will be only very modest growth over the next few years. Indeed, the study predicts that the demand for oil-field chemicals in 1989 will not have recovered to the 1981 peak levels. "This market reflects the imbalance of domestic gas and oil pricing and demand, uncertainty over tax reform, and low crude oil prices," says the company. Moreover, any changes in OPEC pricing, or the level of political turmoil in the Middle East, would alter projections for the oil-field chemicals market.

These same factors certainly are affecting the consumption of oil-field chemicals outside the U.S., agrees the report by Houston. However, unlike the U.S., ambitious exploration and development programs in developing countries will cause consumption of these chemicals to rise sharply, as these countries attempt to cut their dependence on foreign oil imports, and increase their own crude-oil exports. And most of the growth, Houston adds, will be in non-OPEC countries.

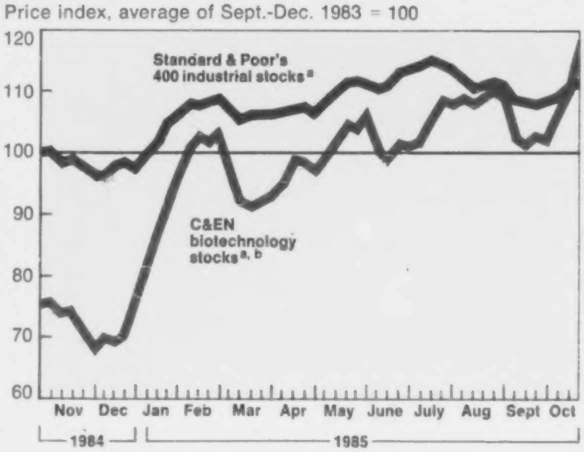
Oil-field chemical sales outside North America will grow to an estimated $3 billion by 1993 from $2.1 billion last year, the study predicts. The most promising market segments over that time will be in well stimulation, production, and completion and workover chemicals, with annual growth rates of 5 to 8%, as oil companies try to maximize production from existing wells.

Additionally, stimulation chemical use likely will grow especially well in areas where output is reaching maturity, or where gas production is being emphasized, such as in the U.K. sector of the North Sea, and in Australia. And production chemicals will show steady growth, as more and more water is produced per barrel of oil.

Price pressures, however, will temper some of the growth. According to Houston, the pressures will be significant in areas such as the North Sea, Saudi Arabia, Nigeria, and Indonesia.

Given the growth facing the industry in areas outside North America, there are opportunities to introduce new oil-field chemicals and technology, and also opportunities to enter the market via the acquisition route, Houston says. In countries pushing oil development programs, the markets "are still open and can be entered if action is taken relatively soon," the company says. However, "attractively priced acquisition candidates and other market entry opportunities likely will disappear within three to five years." □

Biotechnology stocks have overtaken the stock market with recent surge . . .



a Reindexed to average for Sept.-Dec. 1983 period to show relative change. Prices as of Friday close each week. b Based on stock prices for Amgen, Applied Biosystems, Biogen, Centocor, Cetus, Damon Biotech, Genentech, Genetic Systems, Genex, Hybritech, Molecular Genetics, and Monoclonal Antibodies.

. . . but individual stock performance reflects companies' varying fortunes

Company	Latest price[a]	% change[b]	52-week range	
			High	Low
Amgen	$10¾	139%	$10¾	$ 3¾
Applied Biosystems[c]	24⅝	69	27⅜	13⅜
Biogen	11½	64	11½	4¼
Bio-Response	6¾	12	9⅜	3⅝
California Biotech	10¾	72	12	4¼
Centocor	20	90	20¾	8
Cetus	15¼	51	16¾	8⅝
Chiron	9¼	90	10⅛	4¼
Collaborative Research	3⅞	−14	6¼	2¾
Damon Biotech	6½	37	7⅝	4⅛
DNA Plant Technology	8⅞	73	9	3⅜
Genentech	48⅝	51	56½	28¾
Genetic Systems[d]	9¾	39	9⅞	5
Genex	1¾	−80	10⅛	1⅜
Hybritech[e]	27⅝	86	30	14
Molecular Genetics	7¼	0	10¾	6
Monoclonal Antibodies	16¾	56	16¾	7¾

a As of close on Friday, Nov. 1, 1985. b Nov. 2, 1984, to Nov. 1, 1985. c Adjusted for 2-for-1 stock split in March 1985. d To be acquired by Bristol-Myers, pending shareholder approval. e To be acquired by Eli Lilly.

Remember when investment decisions about biotechnology stocks were made by gauging cosmic promises and counting Nobel Laureates? Things have changed somewhat. True, price-to-earnings ratios, the yardsticks dearest to analysts, remain nominal and few among the public companies using biotechnology. And products, particularly those made with recombinant technology, remain scarce. Nonetheless, the investment community, having lost faith in the companies' stocks for much of 1984, now senses a new solidity in the basis for its decisions. The result: a year-long surge in biotechnology stock prices that has culminated in the past month in 52-week highs for several issues.

This reborn investor enthusiasm has a number of sources. Products based on monoclonal antibodies are having great success in the medical diagnostics market. Indications of commercial survivability, such as joint ventures and other long-term agreements, are more common than before. At many firms, losses are narrowing and disappearing. Even FDA's approval of Protropin, Genentech's genetically engineered human growth hormone, though it will neither make nor break the company, has a symbolic power of assurance.

But the most concrete measures of the payoff potential of biotechnology stocks are two agreements made this fall: Eli Lilly's decision to buy Hybritech, and Bristol-Myers' decision to buy Genetic Systems, both in the $300 million range. Such developments light fires under investors.

Both to-be-acquired companies have concentrated on monoclonal antibody technology, so investors turned in October to two other hybridoma-based firms, Centocor and Monoclonal Antibodies Inc. Per-share prices for each reached 52-week highs late last month.

The surge also has elevated shares in such genetic engineering firms as Cetus, Biogen, and Amgen to 12-month high points during the past month. Each has reported management, business, and scientific developments this fall that have pleased the market. Most of the better-known biotechnology issues, in fact, have risen sharply over the past 12 months, lifting their composite value on Nov. 1 to 56% above the year-ago level and 17% above the average value for late 1983, when C&EN began tracking the stocks.

Not all the biotechnology stocks fared so well between Nov. 2, 1984, and Nov. 1, 1985. The per-share price for Genex plummeted after the company lost a vital contract in April, and remains mired 80% below its year-earlier level. Collaborative Research's market value has fallen 14% over the past 52 weeks. And Molecular Genetics' stock price has been flat.

day would have left them with too much going for them and not enough cash," she says.

So enter Bristol-Myers. Like Lilly, Bristol-Myers lacks a window on the fast-growing diagnostics sector. But attractive as the diagnostics business might be, it was probably not the chief reason Bristol decided to buy. "Bristol bought Genetic Systems for its therapeutic research capability," says Parag Saxena, a Citibank assistant vice president in charge of that institution's emerging health care fund. For one thing, he points out, Genetic Systems' diagnostics for sexually transmitted diseases are licensed to Syntex except for its test for the acquired immune deficiency syndrome (AIDS) antibody. "But Bristol-Myers is not paying nearly $300 million for an AIDS diagnostic," Saxena says. "If it had wanted that, it would have bought another firm instead.

"Bristol-Myers is really paying $300 million for being behind in therapeutic research," he says. "There are enough clinical data now to be able to say that this science is

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ETHYLENE IN EUROPE

Rationalization continues despite opening of new facility in Scotland

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CHEMICAL & ENGINEERING
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- **Chemical stocks outperform Dow Jones industrials.** **Page 4**
- **CMA report on safety precautions at chemical plants responds to Congressman's concerns.** **Page 5**
- **Allied-Signal will spin off $3 billion in businesses to form new company, reorganize its remaining business, reduce its workforce.** **Page 5**
- **Dow Chemical will trim its workforce, write down some plastics and chemicals operations.** **Page 6**
- **District court judge orders Shell Oil and the Army to clean up contaminated Rocky Mountain Arsenal.** **Page 6**

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Business

Major fiber intermediates face no-growth future as a result of imports from countries with low-cost raw materials. **Page 10**

International Business

Hugo Lever, director general of the European Council of Chemical Manufacturers' Federations, talks on industry problems. **Page 18**

Government

Approval given by two federal agencies to field-test DNA products draws objections from Congressman, environmental group. **Page 24**

Eastman Kodak asks for a stay of injunction on sales of its instant cameras and film in Polaroid patent infringement suit. **Page 25**

Science

Polymer composed of polyvinyl alcohol, phosphoric acid conducts protons at room temperature. **Page 28**

Technology

Gasoline refiners must meet requirements of high octane ratings at reasonable prices in lead additives phasedown. **Page 30**

Cover Story

European ethylene capacity must be reduced if industry is to be profitable, following startup of 1.1 billion lb-per-year plant in Scotland. **Page 15**

CHEMICAL STOCKS:
Performance outstrips Dow Jones

Although the Dow Jones Industrials Average lately has been getting great press as it consistently hits record highs, chemical stocks also have been rising strongly. In fact, since the first of the year, C&EN's chemical stock index has outperformed the Dow Jones and all other major market indicators, often by wide margins.

C&EN's stock index has increased 31% to 278 from 212 in the first week in January. This in spite of flat production and prices and declining earnings in general for the chemical industry. By contrast, since the first of the year, the Dow Jones Industrials Average has increased 12% to 1435.09; the New York Stock Exchange composite, 17% to 114.36; the New York Stock Exchange Industrials 15% to 130.94; the American Stock Exchange Index, 4% to 237.76; the Over-the-Counter Composite, 6.4% to 306.17; Standard & Poor's 500, 17% to 198.11; and Standard & Poor's 400 Industrials, 15% to 220.06. The Over-the-Counter Industrials have fallen almost 9% to 307.51.

However, chemical stocks enjoyed much of their increase earlier in the year. Since the first part of October, when the Dow Jones began its run, chemicals and the broader average have pretty much kept pace, each rising about 8%.

A number of reasons account for the early rise of chemical stocks. One is simply that Union Carbide stock was so depressed after the Bhopal tragedy that it kept the C&EN index low through the first part of the year. As this stock began to recover toward more normal levels, it brought the index back to where it should be. Carbide's stock price is some 60% higher than it was at the beginning of the year. However, that has been offset some recently by a softening in Monsanto's stock price, caused by its exposure to potential liabilities from its G. D. Searle subsidiary's Copper-7 intrauterine contraceptive device.

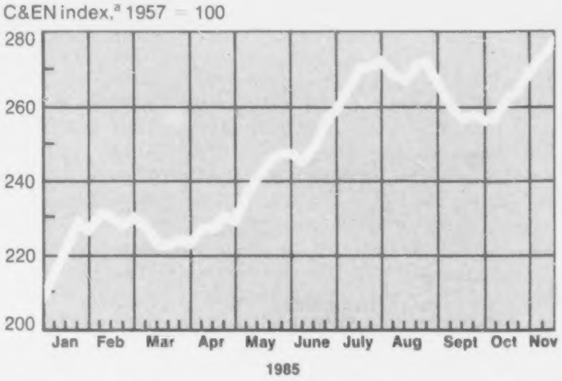
Another reason has been the bullishness on chemical stocks by Wall Street security analysts. One of the earliest of the analysts to get behind chemicals was Peter Butler of Paine Webber, who based his opinion on earnings improvement brought on by restructuring in many chemical companies—a restructuring that has been proceeding since before midyear. More recently, Butler sees positive implications of these restructurings in 1986 if prices firm. Margins, he says, will benefit from lower break-even points and from lower oil-related raw material and energy costs.

Since early October, the chemical stock average has followed the Dow Jones. However, there is a great variation among stock performance in the chemicals group. American Cyanamid and Union Carbide lead the list with 14% stock price rises since early October, followed closely by Dow Chemical with a 12% price increase. The rest of the companies, however, have performed below the average. Celanese's stock is up 5% and W. R. Grace and Hercules' stock each have risen 2%. Monsanto's stock has fallen almost 2% during the period. □

Chemicals have done better than major indexes this year

	Nov. 15, 1985	Jan. 4, 1985	% change
Dow Jones Industrials Average	1435.09	1286.64	11.5%
New York Stock Exchange Composite	114.36	97.71	17.0
New York Stock Exchange Industrials	130.94	113.97	14.9
American Stock Exchange Index	237.76	227.73	4.4
Over-the-Counter Composite	306.17	287.90	6.4
Over-the-Counter Industrials	307.51	336.16	−8.5
Standard & Poor's 500	198.11	169.28	17.0
Standard & Poor's 400 Industrials	220.06	190.64	15.4
C&EN Chemical Stock Index	278	212	31.1

Chemical stocks gain 31% since beginning of 1985



a C&EN weighted stock price index of American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Hercules, Monsanto, and Union Carbide.

Demand for Fiber Intermediates Continues To Slow

Producers forecast imports of apparel to further reduce consumption of major intermediates DMT/PTA, ethylene oxide, cyclohexane

Bruce F. Greek, C&EN Houston

As 1985 draws to a close, producers of large-volume materials that go into synthetic fibers that eventually become apparel and home furnishing are assessing their business outlook for next year. In their forecasts, further small declines in demand are looming. Demand for dimethyl terephthalate (DMT) and purified terephthalic acid (PTA) could be an exception, but demand for both cyclohexane and ethylene oxide very likely will decline.

The general slowing of demand for these fiber materials results from a shift from a domestic to a global economy during the past 10 years. Foreign manufacturers of end products (apparel) produce at lower cost than do U.S. makers. Buyers, therefore, more and more snub U.S. products. For a while, this development didn't bother the fiber materials producers, because they made up sales lost to textile fiber makers and sellers through increased exports. But exports have, or are expected to, become weaker because foreign producers of fiber materials have the advantage of lower raw material costs.

Key Chemicals

This situation results in much reduced profitability from operations for producers of the fiber intermediates DMT/PTA, ethylene oxide, and cyclohexane. Consequently, producers follow a usual practice of shutdowns, especially for old, relatively inefficient, and depreciated plants.

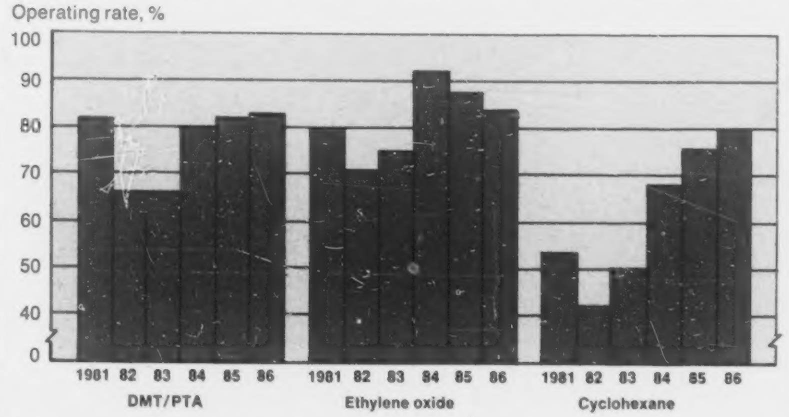
One result of such plant shutdowns is a high operating rate of at least 80% for the remaining plants. Such rates don't always produce high profitability, but at least they improve it. Another possible result: shortages of capacity if demand were to pick up rapidly. Shortages of these fiber materials, however, would be spotty or temporary because of their growing availability worldwide.

In view of the global economy, producers of these and other major-volume organic chemicals will be looking for lowest-cost sources of raw materials, and such sources now are located outside the U.S. As producers shift to foreign sources, plant locations change. This particularly is the case for ethylene oxide, the one product of the three major fiber intermediate materials with the least dependence on fibers. Capacity to make ethylene oxide in the U.S. began to decline when two producers brought on stream plants in western Canada where the raw material, ethylene, costs less because of the lower cost of natural gas. Ethylene glycol, the ethylene oxide derivative used in polyester fibers, now moves with rising volumes in international commerce from various sources.

New limits that might be imposed on imports of apparel in 1986 could delay declines in demand for fiber materials. Forecasts previously have been based on the current rates of increase in imported apparel. However, most industry observers expect that beyond actual bans on imports, the cost differentials are enough to keep interested parties working to find ways around any new limits that will be imposed. Hence, they believe that further declines are in store for U.S. production of fiber intermediates.

For some details of the near-term outlook for the major-volume fiber intermediates, please see the following pages.

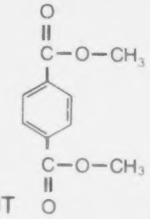
Capacity utilization improved because of plant shutdowns



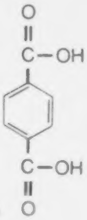
Note: Capacities as of beginning of year and assumed constant during year.
Sources: U.S. International Trade Commission, C&EN estimates

Key Chemicals

DMT/PTA



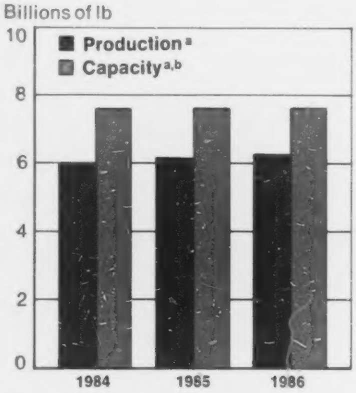
DMT



PTA

- ***Demand better***
- ***Capacity holding***
- ***Prices level***

PRODUCTION/CAPACITY



[a] DMT and DMT equivalents of PTA (1.0 lb of PTA = 1.17 lb of DMT). [b] First quarter.

MAJOR PRODUCERS

Amoco Chemical, Cape Industries, Du Pont, Eastman Chemical

HOW MADE

Oxidation of p-*xylene to make PTA; oxidation of* p-*xylene and concurrent esterification with methanol to make DMT*

MAJOR DERIVATIVES

Poly (ethylene terephthalate) 90%, poly (butylene terephthalate) 5%

MAJOR END USES

Polyester fibers 70%, films 10%, bottles 10%

FOREIGN TRADE

Exports—rising rapidly, may hit 1 billion lb of DMT and DMT equivalents; imports—negligible

PRICES

About 35 cents per lb for DMT; 39 cents per lb for PTA

Of the major-volume fiber materials, only dimethyl terephthalate (DMT) and purified terephthalic acid (PTA) have shown any strength in 1985. The upbeat performance of these two materials derives from a rapid rise in exports of PTA and from continued strong growth in demand for the polyester resins, mainly poly (ethylene terephthalate) (PET), used for making bottles and films.

Next year, demand for DMT and PTA likely will continue to grow, but at a reduced pace as exports grow more slowly because polyester apparel makers will not be helped by efforts to limit textile apparel imports. Demand for polyester bottle resins will continue to increase. Other small uses of these materials, such as poly (butylene terephthalate) (PBT), also will require more DMT and PTA.

Estimates of DMT and PTA production, traditionally fuzzy, made by the U.S. International Trade Commission have been sharpened during recent years, according to various industry sources who say that the problem of overreporting production through possible double counting has been minimized. As a result of this improvement, sources reckon the preliminary estimate for 1984 production of DMT and PTA (equated to DMT) of 6 billion lb could be close to actual production.

Based on that figure, 1985 output of DMT and PTA may be up more than 3% to about 6.2 billion lb. However, if exports turn out to have been unusually large in some months of this year's second half, as they were in the first half, then production could exceed 6.3 billion lb this year. Next year, exports likely will level off, partly in anticipation of more stringent limits on synthetic apparel imports and partly because other countries will increase their competition with U.S. exports. If that happens, the production gain for DMT and PTA could fall to the 1 to 2% range.

Plants making these two polyester intermediates have had no capacity expansions recently, and none are anticipated in 1986. Based on 1985 production of 6.2 billion lb, with nameplate capacity totaling 7.6 billion lb, the average operating rate this year is nearly 82%.

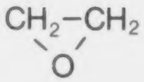
Most DMT and PTA become polyesters, PET, PBT, or some other terephthalate. Roughly two thirds of polyesters become fibers. However, the share consumed as fibers has been dropping as demand for bottle and film resins has grown much more rapidly. (Fiber demand could decline 1 to 2% in 1985.) Besides bottles and film, the miscellaneous uses of polyesters include a host of specialty resins for a variety of small-volume applications.

Polyester fibers are produced largely as filament and staple. The filament has some industrial uses (such as tire cord), but demand has slowed. The apparel uses of filament rise and fall to some degree with fashion and with imports. Demand for staple fibers, generally used in blends with cotton and wool, is influenced by such factors as price of the natural fibers, which can influence the composition of blends because polyester has a relatively stable price and is affected by apparel imports.

Film uses of polyester resins have been surpassed by bottle uses. End uses of films, especially in the various magnetic tape consumer products, are growing well by historical levels, but they are just not up to the growth in bottles. The growth in film uses, including the nontape areas such as packaging, could be in the 5 to 7% range next year.

Growth in demand for bottle resins has surprised many industry sources. Improvements both in molding methods to give greater speed in production of bottles and in applications are part of the reason for this growth. Another reason is the appreciation that grocers have developed for the handling ease of returned polyester bottles. The growth in bottle resins could be 7 to 10% in 1986.

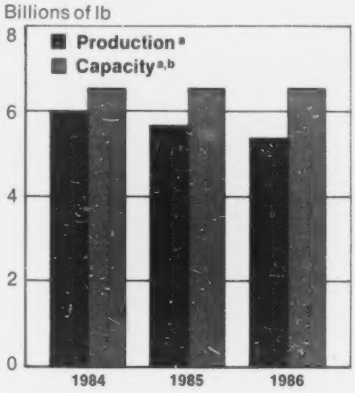
Key Chemicals



Ethylene Oxide

- ***Production lower***
- ***Capacity may fall***
- ***Prices down***

PRODUCTION/CAPACITY



a First quarter. **b** Excludes plants with capacity of more than 900 million lb announced as on standby.

MAJOR PRODUCERS

BASF Wyandotte, ICI Americas, Shell Chemical, Texaco Chemical, Union Carbide

HOW MADE

Vapor-phase oxidation of ethylene with air or oxygen

MAJOR DERIVATIVES

Ethylene glycol 60%, ethoxylates 10%, glycol ethers 5%, ethanolamines 5%

MAJOR END USES

Polyester fibers, films, and molded items 30%, antifreeze 25%, surfactants 10%, solvents 5%

FOREIGN TRADE

Exports—small, about 50 million lb; imports—small, about 25 million lb

PRICE

About 35 cents per lb for merchant sales

Although the ethylene oxide market is not dominated by synthetic fibers, polyesters and other textile uses of ethylene oxide's major derivatives—ethylene and diethylene glycols—still take about a third of production. These derivatives also face the inroads of imported apparel. Except for polyester bottle resins, other uses of ethylene glycols as well as other ethylene oxide derivatives either are growing slowly or are declining.

As a result, demand for ethylene oxide has been slowing this year and is expected to decline further in 1986. Despite some reports that ethylene glycol antifreeze supply has tightened this fall, industry sources forecast ethylene oxide production in 1985 will decline about 5% to 5.7 billion lb. A similar decline has been forecast for 1986 production, bringing production next year to less than 5.5 billion lb. Those declines will follow a gain of more than 400 million lb in 1984 over 1983 production and will put 1986 production below that of 1983.

Pressure is on ethylene oxide prices as a result of declining demand and falling ethylene tabs, even though a relatively small share of output actually is marketed. Likewise, declining demand for ethylene oxide derivatives, especially ethylene glycol, puts pressure on their prices. Consequently, plants have been left shut down for long periods.

Because of current business conditions and expanding worldwide capacity to make ethylene oxide/glycol, restarting of the plants put on standby seems unlikely. Some 900 million lb of nameplate capacity to make ethylene oxide therefore has been removed from the capacity list. Currently operating capacity totals about 6.5 billion lb in the U.S. Purposely expanding this capacity now seems to be unlikely with lower-cost ethylene oxide products available from Canada. For the next few years, ethylene oxide capacity either will remain steady or decline.

If 1985 production totals 5.7 billion lb, then the operating plants will be run at about 88% of nameplate capacity. That's a relatively high rate of operation for organic chemical plants. However, the plant operating rate in 1986 will decline again, with the average at about 83%.

Consumption of ethylene oxide will continue to be dominated by conversion to the glycol, which in turn goes to two major uses: polyester fibers and antifreeze. More than 60% of ethylene oxide goes to glycol, and about 90% of the glycol goes to those two uses. Other uses of ethylene glycol include solvents, deicing fluids, and as an intermediate in making other derivatives. None of the small uses will grow fast enough to affect production of ethylene oxide.

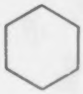
About half of ethylene glycol is consumed in polyesters. By far the largest use is in fibers, now being hurt by apparel imports. If polyester resins used in making various kinds of bottles were not growing so well, the decline in the polyester use of ethylene oxide would be greater. Film uses are smaller than bottle uses, but they are helping significantly to keep up demand.

Some 40 to 45% of ethylene glycol goes into antifreeze. At one time, an important part of the glycol for antifreeze came from impure by-product of polyester manufacture. Now, most of the by-product glycol is cleaned up on site and recycled.

The antifreeze business generally has been trending toward lower volume because of a growing number of cars and trucks on the road with smaller engines. Longer term, the antifreeze business as an outlet for ethylene oxide will be one of little, if any, growth.

The other third of ethylene oxide consumption is made up of many small uses. Some of these, such as glycol ethers, ethoxylates (largely surfactants), and ethanolamines, are large. But none of these have end uses that are growing fast enough to affect demand for ethylene oxide significantly.

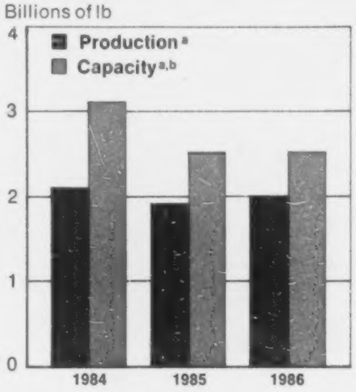
Key Chemicals



Cyclohexane

- ***Production nearly level***
- ***Capacity holding***
- ***Prices lower***

PRODUCTION/CAPACITY



a First quarter. **b** Excludes capacity shut down and not expected to restart.

MAJOR PRODUCERS

Du Pont, Chevron Chemical, Phillips Chemical, Texaco Chemical, Unocal

HOW MADE

Catalytic hydrogenation of benzene; recovery from natural gasoline

MAJOR DERIVATIVES

Adipic acid 60%, caprolactam 30%

MAJOR END USES

Nylon 66 60%, nylon 6 30%

FOREIGN TRADE

Exports—rising to about 250 million lb; imports—small, less than 10 million lb

PRICE

About $1.20 per gal

Producers of cyclohexane almost certainly will post a decline in U.S. sales this year. However, exports of this intermediate, which eventually becomes nylon apparel and carpet, will rise. But the increase in exports won't be enough to reduce pressure on prices—pressure that is heightened by declining prices for benzene, which along with hydrogen is the basic raw material for cyclohexane.

This year's cyclohexane production will fall below 2 billion lb and probably will be less than 1.9 billion lb. That would represent a 10% decline from the 1984 preliminary estimate of 2.13 billion lb made by the U.S. International Trade Commission. Further, it's likely that for the next several years output will remain well below the historical high of 2.4 billion lb set in 1979.

The 1986 prospects for cyclohexane production are not much brighter. Synthetic fiber producers will have the same problems. For example, those who use cyclohexane to make nylon will be looking for ways to negate the effects of imported apparel. Even with moderate success of textile makers in reducing apparel imports, total cyclohexane production likely will rise only modestly, perhaps 5%, because of reasonably strong carpet demand.

With that sort of lackluster forecast, producers will continue to contend with severe price competition. Old formulas for estimating selling prices as a function of benzene prices have changed. Temporary voluntary allowances have been granted on the cost spread between benzene and cyclohexane.

Some producers have shut down cyclohexane units for long periods amid industry rumors that those units would not be restarted. Because the plants have been down so long now, their capacity has been removed from C&EN's estimates, reducing the estimate of the industry's nameplate capacity nearly 1 billion lb to about 2.5 billion lb. By discounting this idled capacity, a relatively good operating rate appears for the remaining capacity. If, for example, 1.9 billion lb of cyclohexane is produced in 1985 from 2.5 billion lb of capacity, then the average operating rate becomes 76% of nameplate capacity, a rate acceptable but not necessarily good by today's standards for making large-volume organic chemicals. In addition, this rate is low enough that it will keep pressure on prices without much relief in 1986.

The use pattern for cyclohexane is not expected to change anytime soon. More than 80% of cyclohexane is used to make nylon that eventually becomes some apparel or home furnishings product. Engineering resins account for most of the other uses of nylons. Cyclohexane also is used as a solvent and in making derivatives of cyclohexanol and cyclohexanone, which are used in making dyes, pesticides, and other specialties.

Nearly two thirds of cyclohexane consumed in the U.S. goes to make adipic acid. The adipic acid and hexamethylene diamine derived from other raw materials are used to manufacture nylon 66. Most of this nylon goes to apparel, which is affected by the pressure that imports put on sales and prices of domestically produced apparel. Because of low profitability in making apparel nylon, at least one producer, Monsanto, has announced plans for a gradual withdrawal from its position as a supplier. Because of that, demand for cyclohexane to make nylon 66 will weaken during 1986.

Slightly less than one third of cyclohexane consumption goes into nylon 6. But phenol is a competitor of cyclohexane in making caprolactam, the precursor of nylon 6. A large part of nylon 6 goes into carpet fibers, which are much less affected by imports than are apparel fibers. Relatively low labor costs are involved in making carpet, reducing the advantages of cheap labor outside the U.S. and keeping imports minimal. The strength in the carpet market will account for most of the net growth in demand for cyclohexane in 1986.

Further Shakeout Expected in Europe's Ethylene Industry

Despite a temporary price increase caused by a series of disasters, capacity will have to be reduced to regain healthy sales and profit margins

Patricia L. Layman, C&EN London

New ethylene plant at Mossmorran, Scotland, began production in October

In late October the first ethylene from the 1.10 billion lb-per-year plant at Mossmorran, Scotland, was sent to Grangemouth, where it entered the U.K. pipeline system.

For the Scots, opening the plant at Mossmorran, at Cowdenbeath, across the Firth of Forth from Edinburgh, was a major event. Construction of the plant, which cost roughly $580 million, was begun in October 1981. Contractor Lummus Crest brought it in below budget and ahead of schedule.

It is Europe's most modern ethylene plant, boasts Essochem, a U.K. unit of Exxon, and joint owner with Shell Chemicals U.K. of the Mossmorran unit. It is also—probably—the last major ethylene plant that will be built in Western Europe for a long time. In the European ethylene business during the past two years, there has been one distinct trend—the industry must reduce capacity to regain any semblance of healthy sales and profit margins.

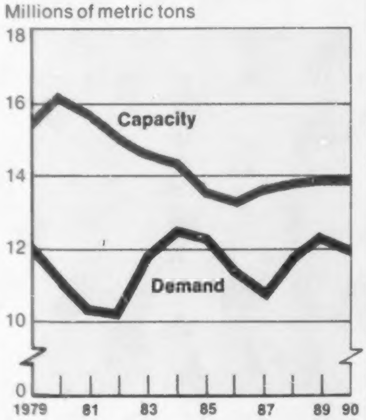
"Producers are beginning to grasp the nettle," and cut back ethylene production, observes Stuart Wamsley, a partner and director of W. Greenwell & Co., securities analysts in London. "Their troubles aren't over yet, but the willingness is there."

Even more than in the U.S., overcapacity has been a chronic problem for the European ethylene business, something that has been painful to adjust to. This summer the situation improved temporarily, but for the unhappiest of reasons: various disasters, including explosions and equipment collapse.

The major outage was Enichem's 1.32 billion lb-per-year cracker at Priolo, Sicily, which suffered a fire and explosion. Despite strong rumors in Italy that Enichem would use the outage as a reason to close the plant and thereby trim employment, the company has let reconstruction contracts, and indications are that the cracker will begin operating again early next year. Similarly, the 827 million lb-per-year cracker at Stenungsund, Sweden, owned by Statoil, the Norwegian national oil company, is back in operation following the repair of collapsed equipment. And the 772 million lb-per-year cracker owned by DSM at South Limburg, the Netherlands, which was knocked out by fire in August, has begun operating after repair.

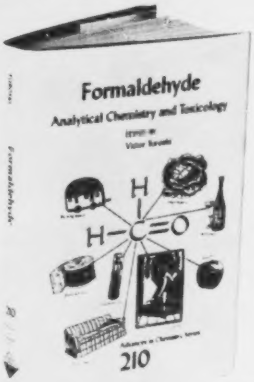
However, industry observers believe it is unlikely that the 441 million lb-per-year capacity of Rheinische Olefinwerke, jointly owned by BASF and Shell, will be rebuilt, after an explosion this summer. Similarly, the capacity of the Texaco plant at Raunheim, West Germany, has been trimmed by 154 million lb to 550 million lb, and the plant is

Ethylene supply gap to open again in Europe



Sources: BP Chemicals, C&EN estimates

Formaldehyde
Analytical Chemistry and Toxicology



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Victor Turoski, *Editor*
James River Corporation

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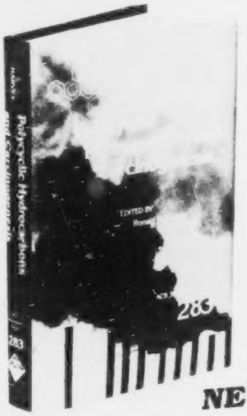
Polycyclic Hydrocarbons and Carcinogenesis



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Ronald G. Harvey, *Editor*
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Reviews and reports the latest research on polycyclic aromatic hydrocarbons, the cancer-causing agents found in polluted air, car exhaust, tobacco smoke, and many foods. Brings together leading experts to provide an in-depth look at why only certain PAH exhibit tumorigenic activity. Focuses on the mechanics of PAH carcinogenesis from a chemical-molecular aspect, rather than from a biological one. Provides a thorough treatment of PAH–DNA interaction, the critical event in the mechanisms of tumor induction. Offers a rational basis for the design of approaches for the prevention and cure of cancer.

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expected to be closed completely by the end of this year. Enichem already has closed a total of 970 million lb of capacity at various crackers.

This summer, however, the supply/demand situation was blissful to long-suffering ethylene producers. Prices firmed, with tabs on the minuscule spot market rising to about 25 cents from 20 cents a lb ($1.00 = 3.0 deutsche marks). Before the accidents, it had been assumed that second-quarter contract prices would be about 22 cents per lb, but they generally were about 22.5 cents.

During the third quarter, the firming became evident and contract prices were in the range of 23 to 24 cents. But spot prices were 19.2 to 19.5 cents, and now that fourth-quarter contracts are being signed, indications are that the average price will be down two cents from third-quarter contract prices.

There certainly were capacity constraints on the market in the first six months of this year, notes John Wyatt, manager of petrochemical services at Parpinelli Tecnon, consultants in Milan. Nevertheless, ethylene output was increasing. "If you extrapolate from the first eight months, you'll find that ethylene production was higher this year than in 1984. So production is there, and the markets are softening."

Overall demand is down, adds Wyatt, because of a declining demand for downstream products. More than half of ethylene in Europe, about 54%, is used for polyethylenes, 18% for ethylene dichloride, and 11% for ethylene oxide, points out Eric V. Edwards, business manager for olefins and gases at BP Chemicals. "Buyers are squeezing the margins now," he says, just as producers squeezed as much as they could earlier, when capacity was tight. Moreover, buyers are squeezing the margins at the same time European producers are watching their feedstock costs being affected by currency exchange rates. During the past two quarters, ethylene prices fell 13%, but because of exchange-rate vagaries, costs for naphtha, which feeds more than 80% of European crackers, fell only 10%.

"Margins are going to continue being squeezed," Edwards adds,

Major West European producers of ethylene line up this way

	Capacity (thousands of metric tons per year)		Capacity (thousands of metric tons per year)
Dow Chemical	1,325	Petrochim	525
Shell	1,240[a,b]	URS	440
Enichem	1,080	Bayer/BP	440
Essochem	1,060[a]	Statoil	375
BP Chemicals	830[c]	Montedison	365
DSM	800	Noretyl	350
Atochem	720[c]	GNP	300
BASF	675[b]	OeMV	275
CdF Chimie	660[d]	Caltex	250
BP/ICI	650	Neste	185
EMP	600	Others	810
Veba	600	TOTAL	14,555

a Includes 50% of 500,000 metric-ton-per-year capacity from newly on-stream Mossmorran, Scotland, plant. b Includes 50% of 450,000 metric-ton-per-year capacity of Rheinische Olefinwerke (nameplate capacity 650,000 metric tons). c Includes 50% of 500,000 metric-ton-per-year capacity of Naphtachimie. d Includes 60% share (250,00 metric tons per year) from joint venture with Qatar. Sources: SRI International, W. Greenwell & Co.

"until overcapacity is fundamentally over. That can happen in two ways: We can pray for increased demand, which is unlikely in the next couple of years, or we can hope another cracker will shut down."

It is probably just a matter of time until that happens. Indeed, once it became clear that Mossmorran production was imminent, Essochem Europe announced that it would close its plant at Cologne, West Germany, by the end of the year. That eliminates annual capacity of 990 million lb per year. And Shell first threatened, then officially confirmed, closure of its 309 million lb-per-year cracker at its Carrington plant, near Manchester, England. Shell in particular has been heavily criticized for the action by the U.K. press, which focused on the net loss of jobs, a touchy subject in England and elsewhere in Europe. Manpower at Carrington is being cut from a peak of 3000 to 500.

It could probably be argued that, had Shell and Esso known what they know now about the conditions the industry faces today, they would never have built the Mossmorran plant. However, given the plant's access to North Sea gas fields and ethane feedstock, powerful political and economic arguments favored the plant. Ethane crackers are cheaper to operate than those fed by naphtha, although it is difficult to get any estimate—even rough estimates—of how much cheaper. U.K. sources, in particular, are loath to comment on a topic over which Imperial Chemical Industries is suing the U.K. government.

According to John A. Collins, managing director of Shell Chemicals U.K., "Although, in isolation, the economics of ethane vs. naphtha were unarguable, the decision was not at all an easy one" to build Mossmorran. "A lot of hard thought and heart-searching went into the question: Could we really justify the huge investment when it would certainly make other naphtha-based ethylene production redundant?" What swung the argument, he indicates, was that Middle East producers, as well as producers in the U.S. and Canada, are using ethane as a cheaper source of ethylene than the naphtha or gas oil Europe depends on.

Despite serious concern in the past several years about the potential impact of ethylene from Saudi Arabia and Qatar, industry sources indicate that it has had little impact on the ethylene industry in Europe.

Says analyst Wamsley, "The Saudis are spreading their marketing around the world. Any impact has been of European making—the Europeans were frightened and began cutting prices too quickly, ahead of the game."

What the Saudis are doing, however, is cutting into the export markets that have become increasingly important to European producers. Wamsley points out that there are about 50 countries around the world producing petrochemicals that were not producing them five years ago. He reckons that if new and announced cracker capacity is built, those countries will add capacity of 44 billion lb per year by 1990.

As expected, the Mideast contributes a sizable chunk of that—roughly 6.1 billion lb. East bloc countries account for another 8.9 billion lb projected capacity. And Far Eastern countries, primarily China, have plans to add 17.1 billion lb. □

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BHOPAL

City struggling for normalcy
a year after disaster
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CHEMICAL & ENGINEERING NEWS

DECEMBER 2, 1985

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- **House committee chairman tells EPA to re-examine its air pollution inspection program after GAO finds it lacking.** Page 5
- **Monsanto to sell oil and other energy interests to subsidiary of Australian firm.** Page 5

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Business

Capital spending by majority-owned foreign subsidiaries of U.S. chemical companies is increasing, despite the leveling off of domestic spending; more and more is going to developing countries. **Page 7**

International Business

Japanese chemical companies improved sales and profits in first-half 1985, but the second half may be less profitable. **Page 8**

Government

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Technology

Study on research needs and opportunities of chemical engineering, prepared under sponsorship of the National Research Council, is optimistic about boosting U.S. industrial strength. **Page 14**

UNION
CARBIDE

Special Report

Bhopal—one year later—is showing signs of emerging from the disaster, but many conflicts, problems, and questions remain. **Page 18**

U.S. Chemical Spending Abroad To Rise

Chemical companies will be spending more for new plant and equipment in foreign countries next year.

U.S. companies seem to be on an overseas building binge. Although capital spending in the U.S. has remained fairly level because of lackluster capacity utilization and soft pricing, spending on new plant and equipment by majority-owned subsidiaries of U.S. chemical companies is moving up for the second year in a row.

The Department of Commerce estimates capital expenditures in 1986 by foreign subsidiaries of U.S. firms in chemicals and allied products will total about $3.37 billion, an increase of 14% from this year. Similarly, the 1985 estimate of $2.96 billion is up 13% from the 1984 spending level.

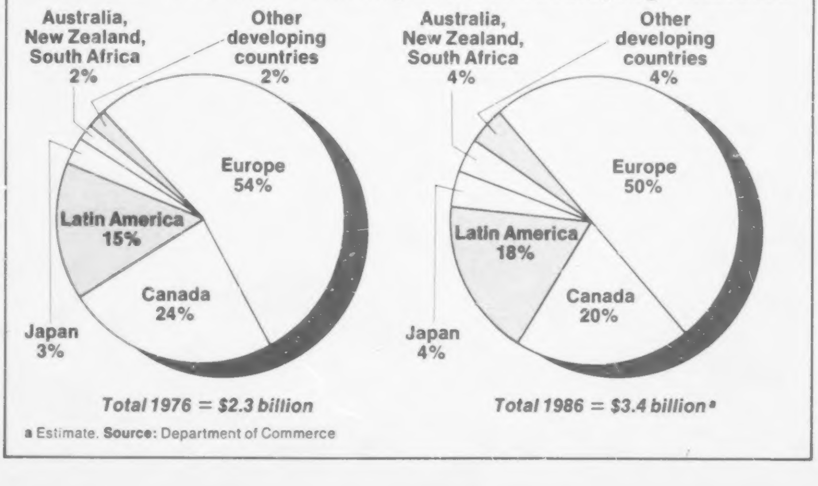
According to the government figures, the healthy increase for chemicals for 1986 is far and above that for all industries. Capital spending for foreign subsidiaries of all industries in 1986 is estimated to increase only 2%. This represents a considerable pullback from 1985, when estimates place capital spending for all industries almost 15% above 1984 levels.

The same pattern holds true for all manufacturing. Capital spending by overseas subsidiaries for this group was estimated up almost 16% in 1985 from the year before. Between 1985 and 1986, however, it is expected to increase just a little more than 1%.

On a historical basis, though, chemical foreign capital spending is still not exactly a bright spot. Since 1976, average annual growth of chemical capital spending abroad has been only about 4%. This happened in spite of the double-digit inflation in the late 1970s. Thus, in real terms, capital spending is probably near or below that of 10 years ago.

In the past 10 years, the chemicals and allied products subsidiaries have shifted capital spending subtly but significantly away from traditional, industrialized countries toward the developing nations. In 1976, 83% of capital spending went to developed countries, with the remaining 17% going to developing countries. In 1985, the developed countries' share had fallen to 80%, with 20% going to developing countries. And, in 1986, the shift will continue with 78% of the capital spending by foreign subsidiaries going to developed nations, and 22% to developing nations, according to Commerce Department estimates.

Chemical investment shifting toward developing countries

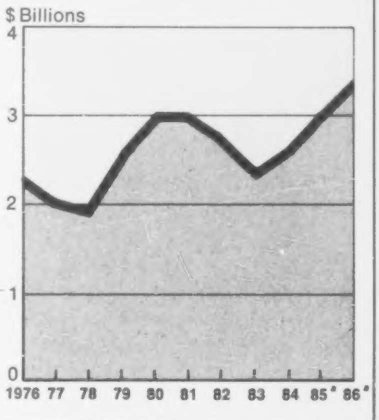


Total 1976 = $2.3 billion

Total 1986 = $3.4 billion[a]

a Estimate. **Source:** Department of Commerce

Spending by foreign subsidiaries up since 1983



a Estimate. **Source:** Department of Commerce

In 1986, chemical capital spending to the developed countries will rise 12%, whereas that to the developing nations will increase more than 20%. This follows an 11% increase to the developed countries and a 23% rise to the developing countries in 1985.

The European Economic Community is the largest market for capital spending by the chemicals and allied products foreign subsidiaries. In 1986, chemical capital spending in Europe will total $1.7 billion, or 50% of all capital spending by foreign subsidiaries of U.S. firms. This is up almost 16% from 1985 spending.

By far the largest slug of capital spending monies to any single country goes to Canada, the U.S.'s biggest trading partner. In 1986, Canada will receive $681 million, or 20% of all capital spending by chemicals and allied products subsidiaries. This is up 10% from 1985, when Canada received almost 21% of all chemical capital spending. Between 1984 and 1985, capital expenditures in EEC increased 5%, while capital spending to Canada climbed almost 22%.

In 1986, capital spending to Organization of Petroleum Exporting Countries will increase 20% to $49 million, after a 51% rise in 1985. ☐

BHOPAL

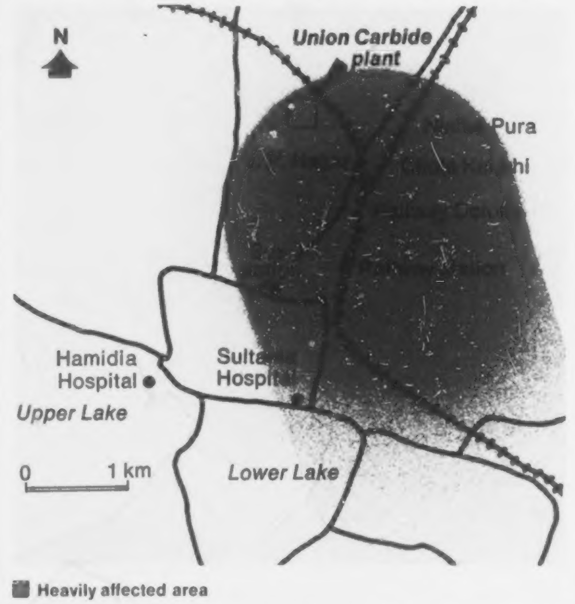
Indian city begins to heal but conflicts remain

Wil Lepkowski, C&EN Washington

Bhopal one year later and the images stream back. The storage tank of methyl isocyanate (MIC)—41 metric tons of it—cooking within from reactions with contaminants. Molecules polymerizing, heat rising beyond 100, then 200 °C. The contents boiling to such frenzy that the tank's concrete casing shakes and cracks. Gases and liquids bursting through a rupture disk and relief valve, then surging through vent lines toward their final release through an overwhelmed scrubber.

Worker panic in the plant, a sleeping community outside as the gas begins to spread. Bodies roused, coughing, crying out, eyes burning and watering. Thousands running, staggering through the dusty streets and alleys, many clutching their babies, not knowing where to run to escape. Unconsciousness, injury, and death by the thousands. Pandemonium in the hospitals. By daybreak, the scene of silence around those left behind: fathers, mothers, children; cows, bulls, goats, dogs, all in final repose. A peace in its eeriness never more heart wrenching. The bodies disposed of by cremation and mass burials.

Escaping gas covered much of Bhopal



Then the local, national, and international responses. Medical supplies flown in. A planeload from the U.S. ordered back by Indian officials already thinking of compensation battles ahead. The sudden incarceration of Union Carbide officers who arrive to offer help. The dispute over the presence of cyanide in the gases. The invasion of U.S. lawyers. The overwhelming outpouring of local help. Schoolchildren, boy and girl scouts, bankers, merchants, the elderly—all transformed to paramedics and performing heroically. The visits by Prime Minister Rajiv Gandhi and Mother Theresa. The tense, circuslike atmosphere of Dec. 16—"Operation Faith" day—when the remaining MIC in an adjoining tank is converted to its final insecticide product, Sevin. The nine-month investigation by India's Central Bureau of Investigation. The now-suspended criminal investigation by a state commission.

Today, Bhopal is a hotbed of unrest, reform, and rebuilding as it struggles toward a future. Mass demonstrations and memorial events are scheduled this month in commemoration of the first anniversary of the disaster. A repentant Union Carbide India Ltd. has prepared a press kit outlining its program of various relief measures. The Poison Gas Struggle Front (known by the Hindi word "morcha"), an infuriating goad to the local establishment, is staging a mass march demanding that Carbide be punished and ejected from India. The government of Madhya Pradesh—the state of which Bhopal is the capital—has scheduled a symposium with an international cast

Photos by C&EN's Wil Lepkowski

An effigy of Carbide management (top) sits at plant gate; Bhopal family displays optimistic smiles

of writers and artists commissioned to deliver eulogies. Over the past year documentaries have been prepared, poems written, plays performed, paintings shown. Poster shows on the misuse of technology have been circulated to science classes in schools throughout the state. In New Delhi an international symposium is being held that will announce to a world kept in the dark thus far the results of Indian investigations of the tragedy's medical effects.

Memorials, too, are being planned. One will be a research center designed along the program lines of the center in Hiroshima, which for 40 years has been following the condition of the atomic bomb victims and their progeny. Another will be attached to a Madhya Pradesh Institute of Disaster Management, expected to be an international magnet for experts in that field. A Bhopal disaster museum connected to Bhopal's stylistic art center, Bharat Bhavan, is in the works. Plans are under way to make the Gandhi Medical College a top-grade research center with particular strength in industrial pathology.

On the surface Bhopal remains today as it was before the calamity: a buzz of open air markets, shops and human beings moving nonstop from dawn to hours past dusk. In one stricken area, signs of physical change stand out: a few television antennas on rooftops, new homes sturdier than the shacks they replaced, drainage canals in place, new paving on the pathways.

The city is no longer as stunned as it was a few months ago, though thousands are debilitated and unable to work. Mental illness as a result of the accident is one of the most serious health problems. The official government death toll is around 1800. Doctors are willing to concede that another 500 to 1000 could have died unaccounted for during the first 24 hours. Official state government figures say 320,000 persons out of Bhopal's total population of about 1 million were affected in some way, about 14,000 "seriously." About $2.3 million has been spent on cash payments to families who lost members in the tragedy.

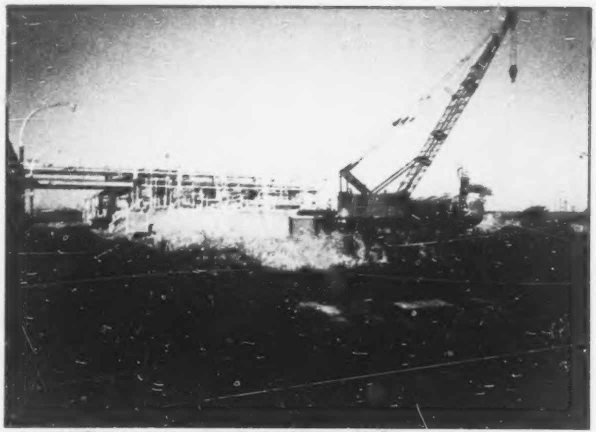
It is difficult, however, to measure what level of help the city needs. Officials tick off assistance figures—cash payments to families with fatalities, numbers treated for lung fibrosis, estimates of stillbirths, pounds of rice and wheat distributed, rupees handed out, the 20,000 x-rays and 35,000 clinical tests performed at Hamidia Hospital, the 1775 beds available now to gas victims.

But the numbers mean little against the magnitude of the disaster, still incomprehensible today. In any of the 30 urban wards, chats with people that were affected by the gas always reveal some unmet need. "These days, everyone is a gas victim," quips one government official. As Bhopal's current mayor Deepchand Yavad indicates, one may as well assume everyone in Bhopal was gassed. But that's a politician talking. Bhopal's pistonlike vitality makes one question claims of any urban malaise there.

Medical care, especially for lung, eye, and intestinal damage, is readily available. Every day hundreds line up at volunteer clinics, mobile treatment centers, or government outpatient facilities around the city. But an issue of high controversy is the extent to which affected persons are being actively sought. Local medical officials say that 34,000 persons have been visited by doctors inquiring about any problems. Records are being kept on everyone being treated. But to critics that isn't enough. Too many victims, they believe, are being ignored.

So there are stories in Bhopal today, and stories within stories—about the cause of the disaster, the dazzling pastiche of short- and long-term health effects, the relief measures, the controversy over the presence of cyanide in victims' bodies, the behavior of Carbide during the early hours of the disaster, the

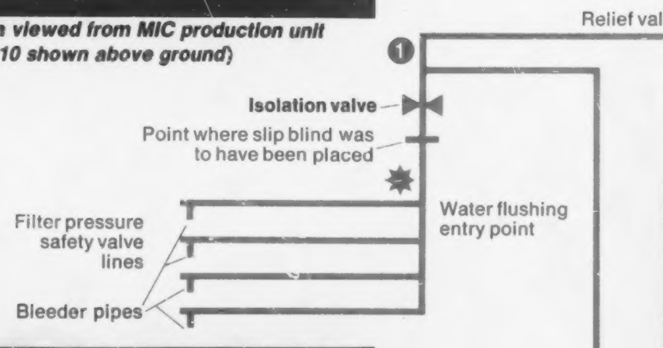
Four theories have been advanced on how water may have entered MIC storage tank

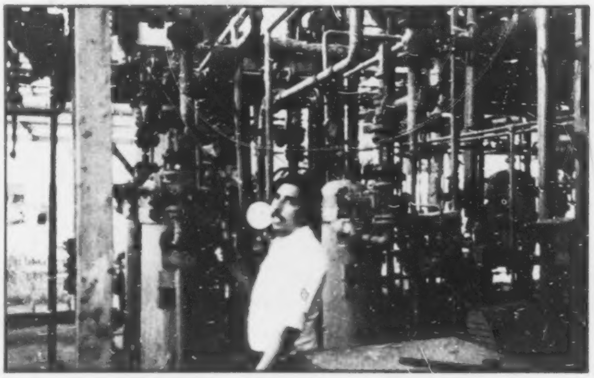


MIC storage area viewed from MIC production unit (tank 610 shown above ground)

① A worker flushing out 2-inch pressure safety valve lines on the evening of Dec. 2 could have failed to insert a slip blind (a disk-shaped barrier) and thus allowed water to flow through a leaky, supposedly closed valve into an 8-inch line. The water moved through this line about 600 feet and then through a jumper line into the process vent line, which led directly to the storage tank

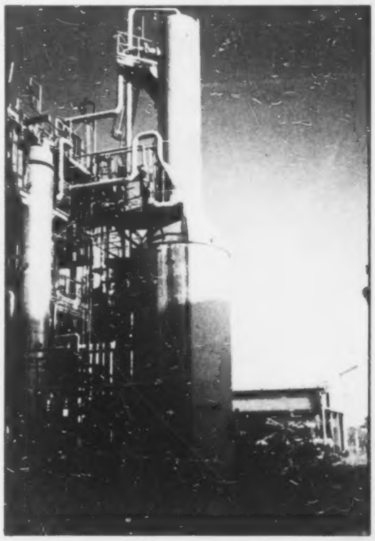
② Water could have entered at some point in the nitrogen line near the tank


Relief valve vent header line
①
Isolation valve
Point where slip blind was to have been placed
Water flushing entry point
Filter pressure safety valve lines
Bleeder pipes
To vent gas scrubber



Area of pressure safety valve lines near MIC production unit

Vent gas scrubber where gases escaped



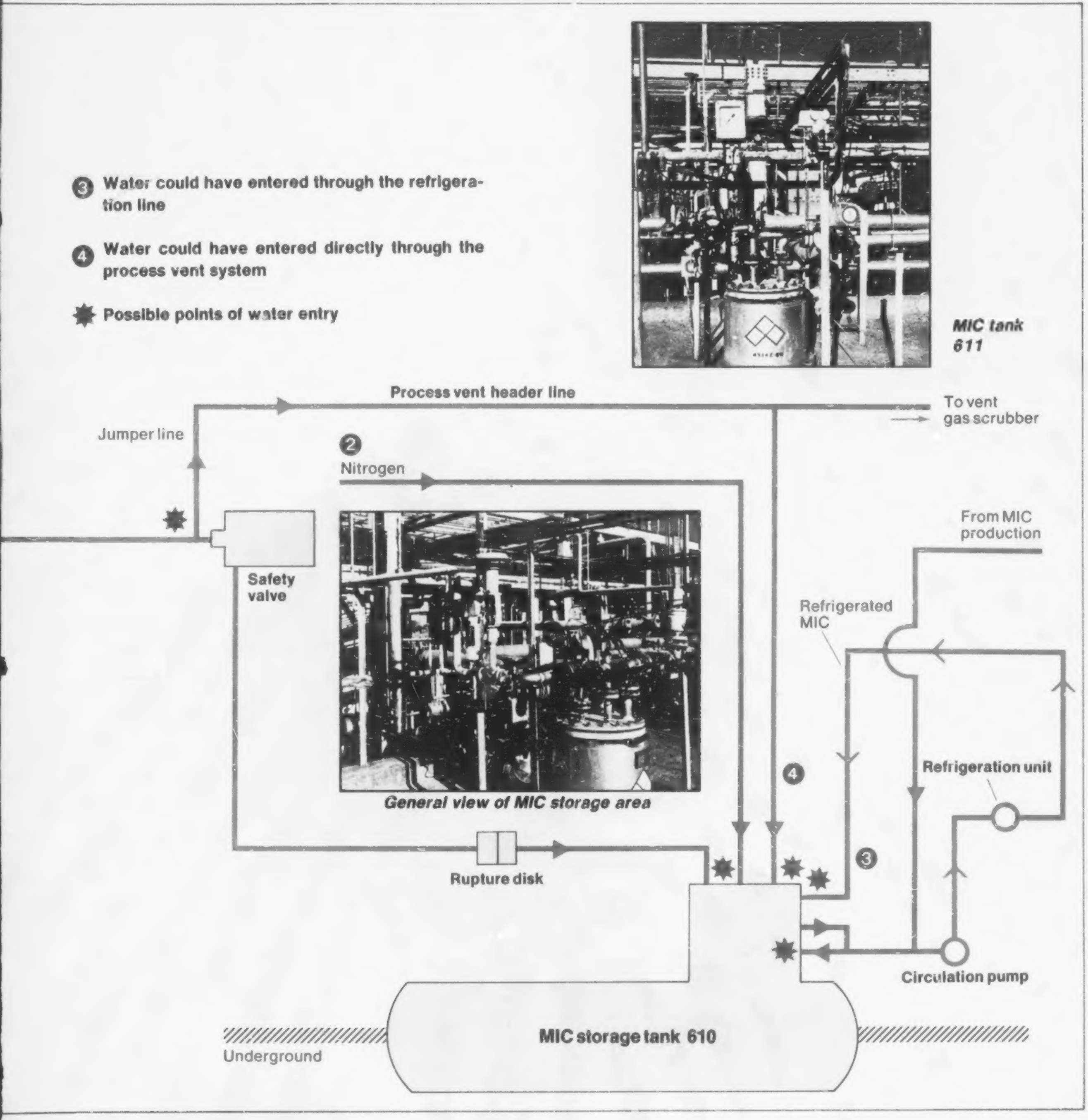
tangled legal story, the state of morality and legality in a culture as contradictory as India's.

The cause: its engineering, its implications

After a year, little is known for certain about what caused the runaway reaction in tank 610 at the Bhopal plant. What is well known, of course, is that the MIC stored in it underwent a hydrolysis reaction that, in turn, triggered a series of heat-generating polymerizations, additions, and degradations.

The resulting pressure burst the tank's rupture disk, blasted through the pressure valve just above it, and the gases surged about 600 feet along the 8-inch relief vent line, past various branch lines, and into the scrubber. They overwhelmed the scrubber's capacity (it was designed only to handle process vent gases, not runaway reactions from storage) and the gases escaped unneutralized.

The flare tower, also designed only for process vent products and moderate flows from the storage area,


③ Water could have entered through the refrigeration line
④ Water could have entered directly through the process vent system
Possible points of water entry
Process vent header line
To vent gas scrubber
Jumper line
② Nitrogen
Safety valve
From MIC production
Refrigerated MIC
Refrigeration unit
④
③
Rupture disk
Circulation pump
MIC storage tank 610
Underground

MIC tank 611

General view of MIC storage area

was shut down for repair. Since the plant was not producing MIC or anything else that night, it made little sense to operating personnel to keep the flare burning. Moreover, a system of pressurized sprinklers that would have formed a "water curtain" over the escaping gases was itself deficient. Water pressure turned out to be too low to reach the height of the escaping gas.

Essentially three theories prevail to explain how it happened. One is sabotage (or mischief) by the insertion of water or contaminants into one of the lines leading into the tank. Carbide says its studies indicate that up to 240 gal of water could have entered this way. No other explanation but one of deliberate intent makes sense, the company says. The vast majority of Indians scorn the sabotage theory.

A second theory involves the "missing slip blind," whereby a worker, ordered to wash out a series of 2-inch pressure-safety valve lines near the MIC production unit, forgot to insert a disk meant to prevent

Browning (left): cupful of water
Bisarya (middle): long-term effects
Bhandari: they feel reassured

water from rising up into the main vent line, called the relief vent header. The water, the theory goes, flowed up the line toward the MIC storage area, passed into a jumper line connected to a process vent line that led directly into the tank. This is the theory that labor, environmental, and popular activists embrace because its source is workers who claim to know what happened.

The third theory is inadvertent contamination by combinations of rust, metallic ions, chloride ion, as little as a "cupful" of water, because of lax monitoring, sloppy maintenance, and inferior technology. Indian scientists doing their investigation tend toward this view and, believing it, are warning the U.S. that until Carbide itself fully understands what happened, it could happen again wherever MIC is stored.

As the UCIL production superintendent, S. P. Choudhary, told C&EN during a tour of the Bhopal plant last month, "We just didn't know that MIC could be that reactive." Choudhary, one of the UCIL management group facing criminal prosecution by the Madhya Pradesh government, rules out all theories that would account for process contamination of lines leading to tank 610. "We do not believe that a small amount of water would have caused this runaway chemical reaction," UCIL says in a statement.

Jackson B. Browning, the parent company's vice president for health, safety, and environmental affairs, adds that the small amount of heat generated by such a small input of water would have been absorbed by the bulk of the contents.

One particular sabotage theory, advanced by Carbide during Congressional hearings after the disaster, also has been ruled out by Choudhary. According to that scheme, the "saboteur" was supposed to have attached a water hose at the source of the nitrogen line that led to the tank and simply let the water run. That scenario has several holes. For one, the source of nitrogen was at least half a mile away from the tank, in an area owned by the company that supplied nitrogen to the Carbide plant. The pressure needed to reach the MIC tank, which itself was under positive pressure, however slight, would have been too great. More telling, though, is that investigations showed no trace of water in the nitrogen line after the accident.

The slip blind theory is also illogical, he says. The reason is that a valve a few inches up from where the slip blind was to have been placed was, records show, closed. Even if the valve leaked, he says, it is improbable that even small amounts of water would have risen about 12 feet to a line that widened to a diameter of 8 inches and then continued some 600 feet to a storage tank that not only was under pressure but, by that route, closed to entry of anything (both the pressure valve and rupture disk were closed tight).

But there was another way not mentioned by Choudhary, via that jumper line between the relief valve line and process vent line. This line, open or shut by valves—how many isn't clear—led directly to the tank. Everyone who has studied the accident agrees this could be a port of contaminant entry. Contaminants might have passed along the relief valve line, across the jumper line, into the process vent line, and into the tank. The scenario assumes a lot of valves that were not just leaky but open. A third option was the nitrogen line at the area of entry into the tank. A fourth involves lines that carried MIC out to a refrigeration unit and back into the tank.

So Choudhary says there is only one option left: "Someone deliberately did it. There are lots of places in any plant where with a simple tool you can detach a linkage and add a contaminant." And a source of water existed a few feet away from the tank. But one needs a motive. Carbide hasn't really supplied the motive, except for newspaper accounts of a radical Sikh group that claimed credit for the disaster. The problem is that the existence of such a group is yet to be verified nationally.

The view of Indian scientists involved in the government's investigation of the accident is that the answer lies in contamination from corrosion. They believe the accident was just that—an accident—but that it was avoidable, and that the fault lay with the parent company, Union Carbide Corp.

"We have proof," says an Indian close to the investigation, "that the process know-how and design provided by Carbide were defective. Any other company in India purchasing foreign technology would have raised questions of why large quantities of stored MIC were necessary. UCIL could have asked something like that. But in this case, here is a plant owned by Carbide. The detailed design was Carbide's. Approval and acceptance of the mechanics and processing were done by Carbide before commissioning."

He goes on to itemize where the Bhopal plant design was deficient. "At the Institute plant, for example, there is an intermediate storage tank between the production and storage units. This is used for continuous sampling of the product. Second, the MIC storage tank in Bhopal was not equipped with safety instrumentation. Sound alarms and flashing lights go off if the pressure and temperature increase at Institute. There was no such warning system at the storage tank area in Bhopal. In addition, the chilling system was underdesigned. At the Institute plant, the storage tank itself has refrigeration coils. The Freon is circulated inside the tank. At Bhopal, the material was taken out and then returned. So the UCIL refrigeration system was underdesigned; the cooled MIC went right back into the tank, which was probably at ambient temperature most of the time. So it probably was never being chilled, even when the unit was on. I don't think the tank could have been cooled much below 15 °C."

Indian government laboratories are attempting to simulate the reactions that might have taken place, based on their own samplings of residues as their own check on Carbide's investigation. "We have taken samples of the tank's wall," says one source. "It's almost impossible to go in the tank now because it still contains highly lachrymating mixtures—trimers, dimers, isocyanates, dimethylurea, biuret."

S. Varadarajan, India's top scientist as director-general of the Indian Council of Scientific & Industrial Research, says he is worried about the safety of those working or living in the vicinity of MIC in the U.S. today. "I think that until the exact cause of the runaway reaction at Bhopal is explained," he says, "there should be a ban on shipments."

The medical results

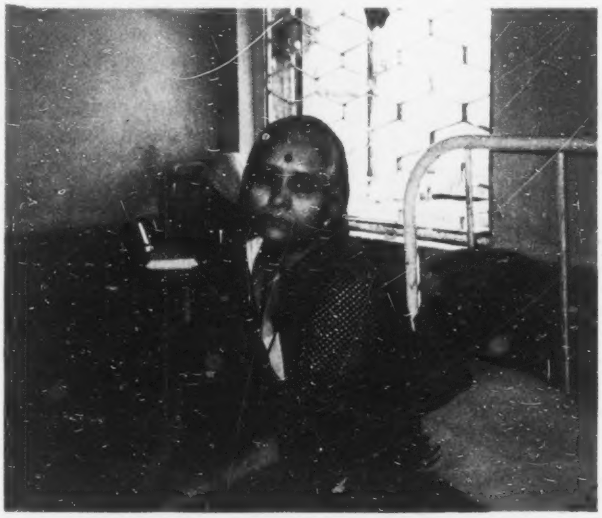
One year after the disaster, Bhopal is one vast experimental ground of industrial toxicology. Every patient is in some sense a toxicological celebrity.

Figures on the total number who died are becoming less controversial by the month. Some activists are still holding out for a figure of up to 10,000, but their voices have quieted. Their claim has been that thousands of bodies were dumped by Army trucks anonymously in mass graves at sites some distance from the city. But no one has located any such graves and few families have come forward to register family losses beyond those reported months ago. So the term "more than 2000" is the best anyone can say. As it is, about 15 gas-exposed persons currently die every month in Bhopal, according to official state estimates. The figure is over and above the 250 or so normal monthly deaths in the colonies that were affected.

Women patients in Hamidia Hospital MIC ward

Medical studies are showing a bewildering array of physical and psychological problems among the affected. Children under 10, when asked to make drawings, inevitably put their crayons to crude depictions of Carbide, gas, and death. Strange sores, susceptibility to tuberculosis, persistently lowered oxygen transport are some of the complications rendered by exposure to the gases.

Some patients are classic cases, such as Dropdi Bai, a 55-year-old woman who has been hospitalized with pulmonary problems ever since the first night. Bai is special, because she is one of the few gas victims of Bhopal who has been under surveillance ever since the leak. She is likely to remain in the MIC ward of Hamidia Hospital for a long time. K. S. Gaur, the physician who administers the ward, says her major



Dropdi Bai: hospitalized since night of accident pathology is bronchiotitis obliterans—blockage of her lungs' air passages. She is being given cortisone to reduce inflammations. She arrived at the hospital in a coma and showed signs of cyanosis. Sodium thiosulfate, the standard antidote to cyanide exposure, was tried twice on her, Gaur says, but with no relief.

Most of the research and treatment in the ward, he says, involves the effect of MIC on the lungs and on lung function. Other studies include the psychiatric aspects, gastrointestinal complications (varied and common), and the long-term complications of drugs such as cortisone, sodium thiosulfate, and Levamisol. "Many symptoms," he says, "can be explained by immunological disturbances."

The Indian agency in charge of continuing biomedical research on the Bhopal tragedy is the Indian Council on Medical Research, headed by V. Ramalingaswami. Located in New Delhi, ICMR has spent $2 million in research so far involving about 150 researchers. And gradually Ramalingaswami hopes most of the followup research and continuous monitoring will be done in Bhopal itself.

The most serious overt problems researchers are investigating involve the lungs, he says. "Whereas eye effects appear to be abating, lung problems are persisting. We're looking at the nature of the disturbances induced by MIC. For those who received moderate to high exposure of the gas, lung edema developed rapidly, and scarring of the alveoli is common. These changes also have made the patients susceptible to pneumonia.

"Extensive studies have shown," Ramalingaswami adds, "that patients have an obstructed as well as restrictive element." That is, they not only absorb less oxygen but breathe in less as well. The restrictive aspect could be due to muscle spasms that constrict and narrow the lumen.

Results of research on Bhopal victims by India's industrial toxicology center

Total studied:
- 508 males, 601 females

Age groups:
- 50%—10 to 35 years
- 17%—36 to 45 years
- 16%—under 15 years
- 9%—46 to 55 years
- 8%—over 56 years

Average monthly income:
- 300 rupees ($25)

Distance from factory:
- 61% less than 2 km
- 31% 2 to 4 km

Chest x-rays performed:
- 903, of which 739 were normal, 164 abnormal
- 91 suggested definite pathology
- 48 showed changes attributed to MIC

Biochemical studies:
- Glutathione level reduced in 30%, indicating hampering of detoxification mechanism and impairment of redox potential of biological system

Immunological studies:
- 55% showed lower phagocytic ability

Chromosomal studies:
- 31% showed chromosomal aberrations

Lung function tests:
- 39% showed ventilatory impairment

Behavioral/psychological studies:
- Difficulty in concentration was most common complaint. Also confusion, poor memory, headache, irritability, depression

"Lung damage is the most serious and most important of our efforts," he says. Bronchodilator drugs are the most common treatment, but if the causes of the lung problems are getting increasingly subtle, other forms of therapy may be needed, he says. Breathing therapy, for example, is just being started. And it turns out that instruction in yoga breathing techniques is the form of physiotherapy chosen. Researchers are saying there is no known technique more effective for expanding lung capacity.

The immunological aspect also could be involved in explaining some of the more subtle, restrictive aspects of the lung damage, he adds. One study involving Indian scientists and Meryl Karol, an immunotoxicologist from the University of Pittsburgh, turned up detection of circulating antibodies after animal exposure to MIC—now called the MIC-specific IGE antibody. "If one detects it in the patients, the finding could lead us to believe the obstructive element could be the consequence of this immunological change."

About 3000 pregnant women were exposed to the gases, according to Ramalingaswami, and miscarriages and stillbirths were frequent. In the first 20 weeks, 436 spontaneous abortions occurred out of 2600 pregnancies. The normal rate in Bhopal is 6 to 10%. "Malformations are still being studied, although doctors are not noticing any increase of obvious birth defects," he says. "The genetic and cancer aspects of the gasing are the biggest unkowns and will have to be followed for years."

Heart surgeon R. K. Bisarya, the Bhopal mayor at the time of the tragedy and now back in full-time medical practice, takes a dour view of the medical situation in the city.

"Long-term effects are showing up now," he says. "And they are much worse than I expected. I am happy about the condition of eyes, however. I thought we'd have thousands of people needing corneal transplants. I'm glad to see that few do. But the long-range effects are bad. People's vitality is continuing to decline. Many feel they are not going to survive. There is lots of colitis, diarrhea, ulcers. A lot of female disorders. Lots of women delivered prematurely, though the fetuses were usually normal."

Bisarya thinks the state medical establishment made a serious mistake by not taking systematic records of the affected people from the very beginning. The focus was too much on treatment and not enough on the careful recording of symptoms.

"Also, I would have expected more involvement from American scientists and physicians," he adds. "Several people I know from Los Angeles said they were willing to come and spend a year or two. They needed government grants to do that. But the U.S. provided no such help.

"Legally, it would have been beneficial to have American scientists. If the case goes to court and our Indian scientists make a claim, Carbide will send in American scientists to rebut them. If we had Ameri-

Worker groups in India push for industrial, community safety

India is a nest of public interest groups. The Bhopal disaster has helped galvanize them, but they are by no means a new phenomenon. Their origins go back to Mohandas Gandhi and his opposition to the caste system and capital-intensive technology.

When India gained independence, young technical professionals believed they could achieve the Gandhian ideals for India through government service. But finding themselves frustrated by the red tape and petty politics of government many gave up on that hope and began organizing science/public interest groups in various states.

The major problem of these groups is that they are frequently attacked by India's merchant class as Marxist. They deny the charges but often counter that Marxist critiques of capitalist economics and politics are often on the mark and should be used as intellectual tools. In fact, they believe capitalism should welcome such sources of stimulation.

The Delhi Science Forum in New Delhi is one such group. Various scientific educational groups that teach science to children in the villages is another manifestation. Another, of course, is the radical Poison Gas Struggle Front in Bhopal. The government has a difficult time dealing with these groups, whose staff members are better educated than the average government professional.

The reason is that, on the one hand, these groups fulfill the Gandhian ideal of pure democracy in the form of free flow of information, which no one can really argue with. On the other hand, they force disclosure of public information the massive Indian bureaucracy routinely prefers to conceal. What they constantly suspect is a large system of bribery and payoffs between industrial and government officials.

Staff members of Society for Participatory Research in Asia

One group that has been particularly successful in maintaining its public interest integrity while creating effective bridges to government is the Society for Participatory Research in Asia (SPRA), located on the outskirts of New Delhi. It claims no leader but says it is run—Gandhilike—by a coalition of staff members.

SPRA defines itself this way: "Participatory research is a methodology based on the belief that knowledge is power, and therefore can contribute towards the empowerment of the poor. It promotes the involvement of the poor and oppressed, their organizations and representatives, in the creation and utilization of knowledge in their own collective interests. It thus attempts to challenge the monopoly over knowledge and its tools in the hands of the few."

Since Bhopal, SPRA is giving a lot of effort to reforming industrial safety laws, regulations, and practices in India and pressuring the trade unions to be more active on behalf of workers. "We're trying to work with social action groups and workers all over the country to inform people in rural and urban areas, slum dwellers, and workers so that they know their situation better," states Anil Chaudhary, a group spokesman. The activity takes the form of meetings, workshops, and a publication program. SPRA does no demonstrating, but does rest its sentiments with the average person. It was part of a team of public interest Indians that toured the U.S. last March on behalf of Bhopal workers who lost their jobs when Carbide shut down there.

The organization has published two major manuals since Bhopal. One is called, "Labor Movements and Legislations in India," a comprehensive history of worker protection in India. The other is "Occupational Health and Safety—A Manual for Activists," an impressively detailed fact book on such topics as noise, heat, chemical hazards, export of health hazards, plant hazards checklist, and occupational hazards and childbirth. Another publication is a model occupational and community safety act that India's Parliament is considering.

"No educational programs for workers or right to know laws exist in any industrial sector in India today," says Chaudhary. "We want to remedy that."

can scientists studying the medical problem we'd have a stronger case."

The Madhya Pradesh health services director M. N. Nagoo remains bitter toward UCIL for its behavior during the first hours. "UCIL never had any direct dialogue with us," he says. "Anything it wanted to do could have been done through the government. [The firm] never bothered about alleviating the conditions of the patients. I was continuously in the hospital for weeks and got no inquiries from UCIL. The night of the leak it never informed us of what to do. I got the alert from the chief commissioner. At 4 AM [company officials] were saying it was nothing more than eye irritation. At 2:15 AM—I still remember the time—people were saying something nontoxic leaked. They could have informed me, but they never did."

This is a subject of special sensitivity to V. P. Gokhale, managing director of UCIL. "We did not have enough knowledge about the acute, long-term effects of MIC at the time." He says the company sent telex messages to Carbide the day after the tragedy seeking answers, and that Carbide sent eye and lung specialists within a couple of days. He points out that the plant dispensary was treating 6000 victims. "On Dec. 3 we flew in our physician and brought along with us medicines, oxygen, respirators, and 120,000 rupees ($10,000)," he

A Bhopal portfolio

Grim reminders of Bhopal disaster are Carbide's plant (above), ashes of cremated victims (far right), and children exposed to gas, photographed shortly after tragic gas leak from plant

says. "At that time there was a lot of pressure on the medical community. Whatever supplies we gave were not acknowledged in writing. Then came the controversy over cyanide. That led some people to believe that UCIL deliberately misled the medical community. I don't know what our doctors were telling people. But the accusation that UCIL withheld information on long-term effects does not make sense. The truth is that we were unable to communicate to them what they needed to know."

Volunteer health organizations are upset with the government because they feel Madhya Pradesh physicians continue to underplay the extent of damage to women. Rani Bang, a Bombay-based gynecologist, reported in March that of 55 studies of women, 94% developed gynecological diseases like leucorrhea, 79% pelvic inflammatory diseases, and 46% menstrual bleeding. "Lactation suppression, impotence in husbands, stillbirths, and abortions have been other effects," her report stated.

Says Anil Sadgopal, leader of the Bhopal Poison Gas Struggle Front: "We were unwilling from the very beginning to accept the ways government doctors were downplaying the extent of problems. On Dec. 27 Ishwar Dass, then health secretary, was declaring that only eyes and lungs were affected. The rest of the systems he said were normal. To us activists in the field, working with the injured, the statement was shocking. Our survey teams had established that almost every organ of the body was showing one or another affliction. Gynecological disorders in various forms were observed by our doctors. And they are still showing it now."

But although medical disputes continue, especially over cyanide toxicity, much of that strident period is past. N. R. Bhandari, superintendent of Hamidia Hospital, says women need reassurance as much as anything. He believes that publicity has been so intense around dangers to newborns that anxiety is common among pregnant women. Ultrasonic fetal monitors have helped calm some women. "When they see their living baby on the screen, they feel reassured," he says.

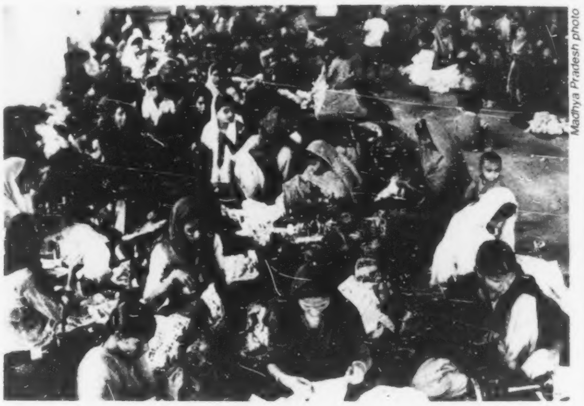
The relief efforts

Much of the agitation that has roiled Bhopal over the past year—riots, police beatings, storming of the state government's offices, a takeover by the morcha of the Carbide factory grounds—was in response to the slowness with which the Madhya Pradesh government was responding to the needs of the victims and to Carbide's unemployed workers. A superficial look at the gas-affected area, however, leads a visitor to conclude that significant changes are taking place.

Uniformed children sit attentively in one-room shacks that serve as schools. Little assistance centers dot the colony, one providing counseling services for women, another dispensing high-protein bread. Small shops are opening with money either given by the government or loaned to the villagers by, yes, UCIL.

In the accident's aftermath, Madhya Pradesh chief minister Vora visited gas-affected colonies (bottom left), new hospital began rising near Carbide plant (left), and center was established to teach sewing skills to women from gas-affected colonies

Madhya Pradesh photo



Madhya Pradesh photo

Some new homes, built solidly of stone, are seen, contrasting sharply with the crude tin and burlap shacks that still predominate. In one sense, the gas-affected people are the new elite of Bhopal. Some of those who never had it so bad now have never had it so good and are the object of envy by the rest of Bhopal's poor.

Down Berasia Road, which divides the colony from the UCIL plant, the government has opened cottage industry training centers. In one, more than 100 women, many widowed, work at sewing machines, turning out garments that the state will distribute in the remote villages of Madhya Pradesh. A knitting operation was opened in October. Last month a hosiery production unit got started. Men are being trained in new work, including television repair.

Dass, the Madhya Pradesh first secretary in charge of all relief operations, says the government has plans to build an export-oriented business that will produce fine products for the international market. Dass is a Ph.D.-holding organic chemist who long since has abandoned the lab for government service.

A person like him was needed, for through May, the situation was getting wildly out of hand in Bhopal. A drought was threatening the area's economy. Its chief minister, Arjun Singh, had left suddenly to take up duties as governor of Punjab. Because of the lack of leadership, relief measures were in chaos. Medical treatment and record keeping was a mess. The gas-affected people, led by the morcha, were demanding more medical, nutritional, financial, and community help. And the UCIL workers were getting restive by prospects of no work. May and June were marked by demonstrations and jailings of morcha and labor leaders, as the cyanide controversy began bursting into the headlines.

By May, the central government began intervening. The chief finance minister, V. P. Singh, the most powerful general policy figure in the Gandhi government, visited Bhopal and promised to break the financial logjam. At the same time, the state's new chief minister, Motalil Vora, began paying surprise visits to the affected colonies, meeting with people to hear their grievances.

Says Dass: "The morcha was dissatisfied with the way the scientific bureaucracy failed to convey information on anything important to the people. A motley crowd led by leftists came together and took a confrontational position.

"June 25 was the watershed. Since then they haven't been able to consolidate. When I took charge, I felt that once the people see what we are trying to do, the agitational scene will lose its relevance. Such organizations do have a role to play. I told the demonstrators to try to take over the wards and take up some concrete activities like comprehensive care."

Carbide is attempting to inject a permanent presence in Bhopal's rehabilitation efforts, and Dass says its efforts are always welcome. It is funneling some money in by anonymous means and has established a trust fund of about $200,000, made up of contributions from Carbide's Indian and U.S. employees, to be used as a source of loans to survivors who want to start businesses. Clinics funded by UCIL are in operation. A leather products business has been started, funded by UCIL. The most ambitious project is a housing project that is currently going up.

The future of the plant site is still being determined. Carbide offered to make batteries there, or reopen the pesticide formulation plant. But the government would have none of that. Carbide has a 99-year lease on the site for industrial operations at a yearly rental of $600 a year. It has no intention of giving up the land and probably will appeal any order to depart.

"We have all our buildings and plant on the site," says UCIL's Gokhale. "There is a sizable investment there." The future of the pesticide research lab on a hill overlooking Bhopal is also unclear. Morale is poor there. Several researchers have departed. The government has suspended its tax-exempt status. It could be nationalized, or closed.

Not everyone is satisfied with the relief schemes in Bhopal. Sadgopal's morcha continues to agitate for more input for the affected people. The Rashtriya Abhiyan Samiti, another of at least a dozen public interest groups that have settled in Bhopal since the disaster, is one of Dass' sharpest critics. The group calls Dass' rehabilitation scheme a "cruel joke" on the victims.

"Only the government and its experts can explain how an aerodrome, a railway station, a botanical garden, a boating facility, and a swimming pool are related to the rehabilitation of gas victims," it says in a statement. "The government has proposed an expenditure of [$85 million] on such irrelevant schemes. There has been no attempt to satisfy the needs of the 80% worker population of the gas-affected areas employed as railway coolies, day laborers, bidi (cigarette) makers, tailors, petty businessmen, textile and paper mill workers, railway gangmen and peons, whose health, housing, and employment have been seriously affected."

J. P. Nagar is the showcase of the affected communities. But at other areas such as Kazi Camp and Railway Colony, off the official Bhopal gas tour, the pace of recovery seems slower, though government clinics and those run by various voluntary groups keep open house in all the colonies. At the Railway Colony, stories tell of residents there being forced to pay for their own treatment and care, including trips to Bombay for special care.

The relief story in Bhopal will be a source of continuing controversy for perhaps years.

Thiosulfate/cyanide issue is most controversial

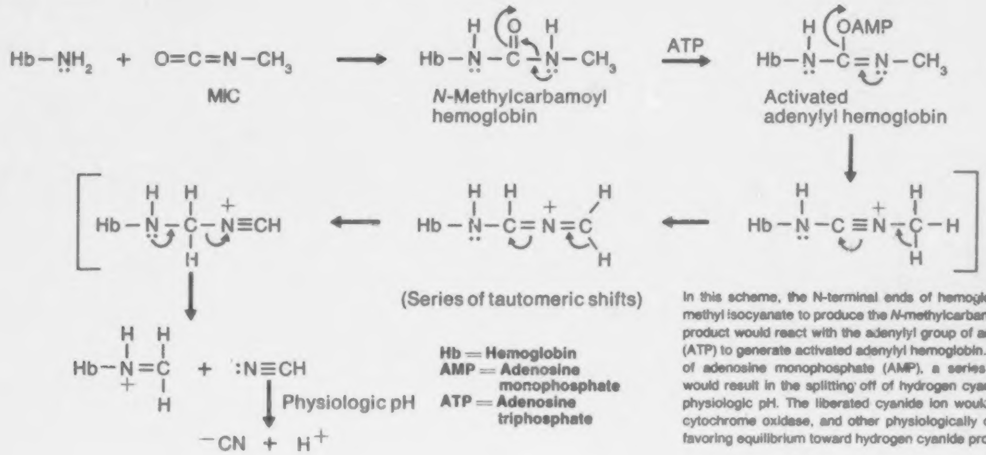
The issue over whether many of the Bhopal victims were and still are exposed to some form of cyanide poisoning is the most controversial aspect of the tragedy, and the most politically explosive. Indeed, as one Gandhi Medical College physician observes, "The cyanide issue is more sociopolitical than scientific." In the beginning, Madhya Pradesh medical officials and Carbide physicians denied any possibility of cyanide exposure among the gas-affected victims. Yet, on Dec. 6, three days after the event, scientists of India's Air Pollution Control Board were detecting cyanide at the MIC storage tank area and 50 meters downwind. At about the same time, doctors at Bhopal's hospitals were treating victims for cyanide exposure. (The presence of cyanide at the tank site is an intriguing notion, since the leakage was almost exclusively reported to be at the scrubber.)

By February, the Indian Council of Medical Research finished its study of cyanide exposure and in a March report recommended continued sodium thiosulfate treatment. It said that, although there was no longer any direct exposure to cyanide, reactions in-

Photo by Nagabhushan Rao

Dass (left): a deliberate act
Varadarajan (middle): people in U.S.
Gokhale: not enough knowledge

Proposed mechanism for generation of cyanide in the body after exposure to MIC


MIC
ATP
N-Methylcarbamoyl hemoglobin
Activated adenylyl hemoglobin
(Series of tautomeric shifts)
Physiologic pH
Hb = Hemoglobin
AMP = Adenosine monophosphate
ATP = Adenosine triphosphate

In this scheme, the N-terminal ends of hemoglobin would react with methyl isocyanate to produce the *N*-methylcarbamoyl hemoglobin. That product would react with the adenylyl group of adenosine triphosphate (ATP) to generate activated adenylyl hemoglobin. Following elimination of adenosine monophosphate (AMP), a series of tautomeric shifts would result in the splitting off of hydrogen cyanide, which ionizes at physiologic pH. The liberated cyanide ion would bind to hemoglobin, cytochrome oxidase, and other physiologically critical enzymes, thus favoring equilibrium toward hydrogen cyanide production

Source: Harold Teague, Pembroke State University

volving the body's "cyanogen pool" and biochemical by-products of MIC could be accounting for the success of sodium thiosulfate treatment.

The report pointed to improved condition of treated patients and increased urinary concentrations of sodium thiocyanate after treatment, indicating the presence of cyanide in the system. Since sodium thiosulfate is a drug without appreciable side effects, the council said it would do no harm to continue treatment. Volunteer physicians were reporting permanent recovery in many cases from the treatment. But local doctors were by then opposing it, claiming that any positive results were due to psychosomatic responses. Patients, they said and say now, kept coming back for booster shots that really were doing no good.

"I feel that in the initial stages there was no doubt cyanide was present," says health services director Nagoo. "The toxin that was fixed to the tissues could well have been cyanide. But a year later it is difficult to believe cyanide is present and could be detoxified."

The issue has taken on fierce political and social overtones in Bhopal, causing riots, beatings, and jailing of both morcha demonstrators and volunteer physicians. At one point last summer, police under orders from Madhya Pradesh authorities, broke into thiosulfate dispensaries run by volunteer physicians, arrested them, and confiscated the thiosulfate supplies.

"The cyanide issue is important not merely for its biomedical/toxicological aspects," declares morcha leader Sadgopal, a biochemist who received a Ph.D. in 1968 from California Institute of Technology under James Bonner. "The real importance lies in the legal ramifications. To us it is important because a serious attempt would be made by Carbide lawyers to establish that a large portion of the lung damage can be explained by such things as endemic tuberculosis. It is at this point that the issue of cyanide toxicity would become crucial because if you can establish that so many thousands of people received clinical benefit from sodium thiosulfate injections and you have a clinical record, then you have established that they were suffering from cyanide or cyanidelike toxicity. If sodium thiosulfate gives relief, it is a specific antidote and its effect is shown by a specific chemical urine test for thiocyanate. High levels of it in urine would measure the amount of exposure."

What Sadgopal did manage to do, with the legal help of a Bombay activist lawyer, Indira Jaisingh, was to win an order by the chief justice of the Indian Supreme Court. The chief justice instructed the Madhya Pradesh government to allow the distribution of thiosulfate to volunteer groups, like the People's Medical Center, to continue their treatment. Sadgopal says his case was strengthened by Heeresh Chandra, chief pathologist at Gandhi Medical College in Bhopal. Chandra had been one of the first to detect symptoms of cyanide poisoning and to this day continues to insist that cyanide is still being generated in patients and that thiosulfate therapy is useful. What helped, too, were the March recommendations in favor of thiosulfate by Ramalingaswami's ICMR, which Madhya Pradesh physicians refused to act upon. In a development last month, Sadgopal and Jaisingh also convinced the chief justice to appoint Sadgopal and forensic scientist Chandra to a seven-member committee with direct oversight over the entire clinical program in Bhopal.

The cyanide issue, scientifically speaking, appears to have two aspects. One is direct exposure, which could have occurred during the first hours in the areas closest to the plant. The technical book on this one is closed, although the mystery of why exposure was so vehemently denied by officialdom isn't. The second aspect is indirect exposure owing to unusual generation of toxic amounts of hydrogen cyanide in the body after exposure to MIC.

Worker and colony elder at site of mosque construction

"The way the ICMR scientists have explained the mechanism of cyanide generation makes some sense," says biochemist Sadgopal. "That is the concept of the body's cyanogen pool generating cyanidelike radicals continuously in the bloodstream. When released, they could hook onto the hemoglobin, or to some other enzyme, or to cytochrome oxidase (a key respiratory enzyme). They could either block the respiratory system at the cellular level or modulate the behavior of the hemoglobin in releasing or carrying oxygen.

"Now, the sources that feed into the hypothetical cyanogen pool could be many. One possibility could be MIC linked to a peptide or amino acid, which is gradually hydrolyzed by enzyme action. Then MIC could be converted into thioisocyanate by the transfer of sulfur from thiosulfate. Thioisocyanate existing in equilibrium with thiocyanate is one possibility."

The scheme, though general, does make some hypothetical biochemical sense. MIC binds to hemoglobin in a carbamylation reaction. That binding was a common clinical observation at Bhopal. (The isocyanate-hemoglobin reaction is used to some advantage clinically, too. It is a well-known treatment for sickle cell anemia, because the reaction converts the sickled hemoglobin to a more normal shape.)

A paper just submitted to the *Journal of Chemical Education* by organic chemist Harold Teague of Pembroke State University theorizes a series of reactions by which the MIC-hemoglobin combination could result in the generation of hydrogen cyanide. The reactions involve adenosine triphosphate and a series of electron shifts, resulting in the splitting off of hydrogen cyanide, which would then itself bind to hemoglobin. The success of thiosulfate therapy would then make some sense.

So scientifically, the cyanide issue is intriguing; politically it raises adrenaline levels; and legally it waits a final verdict as to its importance. Right now, it is no consideration in the current legal battle between Carbide and the government of India.

Chemical safety reform in Madhya Pradesh

If words alone are the criterion, Madhya Pradesh appears to be well along the way to cleaning up its industrial safety practices. In the aftermath of Bhopal, says Madhya Pradesh Labor Secretary S. C. Gupta, the first thing his department did was assemble a team of experts to undertake a quick survey of industries that handle chemicals in the state. The team surveyed 61 chemical units, found some deficiencies, and then suggested remedial measures.

"Another action was to give an assignment to Engineers of India Ltd., a design firm, to do safety audits of 11 industries engaged in the manufacture or use of chemicals," he says. "They inspected those units and gave interim reports and pinpointed the deficiencies that were detrimental to health and safety. We wanted to know whether they were detrimental to the health and safety of the workers and whether there could be dangers posed to localities.

"In another activity, the state has established a committee of senior secretaries to examine the question of setting down norms and procedures for ensuring the protection of villages situated in areas affected by the construction of pollution-prone industries. They have a large charter, covering steps for the approval of their operations on environmental grounds, criteria for site selection of major industrial complexes, and procedures for the regular inspection and certification of such facilities. The committee is also examining which parts of existing laws and regulations need to be modified or amended.

Gupta put together another team to examine the central government's Factories Act rules and regulations that directly relate to industrial health and safety. "We found certain lacunae," he reports. "If our inspectors were to find a certain deficiency in a unit, they had no power to suspend operations. There was also no penalty for failure to carry out the recommendations. So we are suggesting that inspectors be given the power to revoke or suspend until deficiencies are rectified. The current penalties are no deterrent. They give three months to carry out improvements, plus a fine of only 2000 rupees."

The Factories Act does not obligate company management to keep communities informed of dangers, nor does it require preventive measures that could be taken. "Many of us did not know the UCIL factory could pose such a danger," Gupta says. "[Management] never mentioned anywhere whether any raw material was toxic. [It] had no obligation to tell us about any change in the process."

In New Delhi itself, reform of the Factories Act is under debate. The urge for reform certainly seems to exist in India, especially in the chemically developed areas around Bombay. The press is quick now to report leaks all over India. Each state has appointed independent inspection teams, trained in chemical engineering, to survey danger spots.

Crucial court decision approaches in suits by Bhopal victims

It has been 10 months since most of the 119 lawsuits filed in the U.S. on behalf of individual Bhopal victims against Union Carbide were consolidated in the U.S. District Court for the Southern District in Manhattan. Nearly eight months have passed since the government of India sued Carbide in the same court, and more than four months have elapsed since Carbide moved to have the actions dismissed on the grounds that the U.S. was not the proper forum for the case. Now, with much of the preliminary legal work completed, the stage is set for a decision crucial to all parties.

On Jan. 3, 1986, attorneys for both sides will present oral arguments on the dismissal motion to federal judge John F. Keenan, who is presiding over the proceedings, in the Manhattan court. Judge Keenan's ruling on the dismissal motion could come on the same day or after a period of consideration. It is also possible, though not expected, that the judge could request additional information before issuing his ruling.

Whatever the timetable, the future course of the case in the U.S., and, probably, the tack of future settlement negotiations, hinges on the ruling. If the case remains in the U.S., Carbide could ultimately face American-scale damages, which are far higher than those generally awarded for personal injury in Indian courts. Therefore, legal experts believe, the company's bargaining position would be weakened and India could demand more money to settle its suit. On the other hand, a ruling for dismissal would strengthen Carbide's negotiation stance. Negotiations have been stalled, apparently awaiting the court ruling, since a reported $300 million offer by Carbide was turned down by the Indians last summer.

Key to the ruling is the judge's interpretation of the briefs and oral arguments in the light of forum non conveniens, a legal doctrine that can be used to determine whether the forum chosen by the plaintiffs is a suitable tribunal. Carbide's contention, under the doctrine, is that the actions should be moved to India because the disaster occurred there, the plaintiffs are all Indians living there, "essential" witnesses and evidence are located there, and many suits have been filed there. Underlying the company's point of view is its insistence that whatever liability may be involved should not include Union Carbide Corp., the parent firm, but only Union Carbide India Ltd. (UCIL), the company which operated the Bhopal plant and which is owned 50.9% by the parent firm.

Attorneys for the plaintiffs, on the other hand, have argued that the parent firm is responsible for the acts of its subsidiary. Acceptance of that premise, they contend, means many important witnesses and much crucial evidence on the design of the plant and control of its operation are located in the U.S. And that, they say, makes the U.S. court the proper one.

Because Carbide holds that the parent firm is not liable in the case, it wanted to shield itself from discovery inquiries until after the forum issue was decided. The plaintiffs, conversely, argued that since the liability of the parent firm was critical to their contention that the case should stay in the U.S., they needed a discovery period before final arguments on the dismissal motion were heard. Judge Keenan, looking for a middle road, allowed a limited discovery, under which only interrogatories related directly to the forum issue were permitted.

Most of the information learned in discovery will not be made public until the briefs are filed, but Bud G. Holman, Carbide's chief attorney, says his side's inquiries uncovered "an enormous amount of information favorable to Union Carbide." He asserts, for instance, that involvement of Indian engineers in the design and construction of the Bhopal plant was greater than previously thought. Michael V. Ciresi of Robins, Zelle, Larson & Kaplan, the law firm representing India, declines to comment on what his side learned from discovery, citing a confidentiality order by the judge.

At the same time that the legal watershed grows nearer, Carbide seems to be increasingly emphasizing the theory that sabotage, rather than an inadvertent action, was responsible for the accident. Lawyer Holman admits he has no direct evidence of sabotage, but says that getting the water into the tank "was so improbably inadvertent that our conclusion is that it was deliberate." He adds that the plant library contained information that would have been useful to a saboteur and that it was open to most employees.

Ciresi scorns the sabotage theory as "the product of a runaway imagination. They have no facts to support it," he says, "and they know it."

If Judge Keenan rules in favor of Carbide on the forum issue, the plaintiffs will have the right to appeal. If the case is kept in the U.S., Ciresi says, the plaintiffs' attorneys will try to move it to trial quickly, with discovery cut off by the end of June, the summer for pretrial motions, and an opening trial date of Sept. 1, 1986.

David Webber, New York

But although the Indian technical community is paying heed to the country's own deficiencies, it is also insisting that the West refrain from regarding the country as a technological backwater.

"Chemical accidents before and after Bhopal in the developed countries show that chemical technology is not necessarily managed more intelligently there," says chemist G. Thyagarajan, a Council of Scientific & Industrial Research laboratory director and head of the government's technical Bhopal investigation team. "Runaway reactions do not make a distinction between developing and developed countries. Did Flixborough [the 1974 chemical disaster in England] happen in a developing country? Did the Seveso poisonous gas leak occur in a poor developing country? Why did a toxic gas leak occur last August in a Union Carbide plant whose safety was said to have been beefed up by the spending of $5 million?"

There is no lack of scientific and technological talent and imagination in India. Indian scientists point

New house in J. P. Nagar (left)
Thyagarajan (above): no distinction

to the giant government-owned Indian Petrochemicals Ltd. (IPCL) complex at Baroda that licenses western technology, and the privately owned National Organic Chemicals India Ltd. (NOCIL) pesticide plant at rural Chiplun, south of Bombay. Managers in those plants all make the point of saying UCIL's operation at Bhopal was not representative of anything near what indigenous Indians can do. Discussions with Indian scientists, engineers, industrial management figures, bureaucrats, journalists, and activists all lead to that one point. The feeling is that Carbide bungled Bhopal badly. It was trying to push a product, Sevin, whose market potential in India was dwindling. It knew it, was hoping to sell off its Bhopal plant, and had virtually given up on it. The stage seemed set for disaster.

As far as the long-term effects of Bhopal on India's consciousness, even activists are pessimistic. Says Vijay Varma, a physicist at Delhi University, who is active in the reform of science education in Madhya Pradesh: "Bhopal happens and the general feeling is that it is an act of Providence, not likely to happen again. I think the West will learn from Bhopal more than we will here. As long as the government is doing the enforcing, the process will be too corrupted. The only meaningful solution is for independent experts to take over enforcement."

Even activist Sadgopal has second thoughts. "It is amazing that we have not been able to explain the sociopolitical issues involved in the Bhopal tragedy even to the people of Bhopal—the role of the multinational, the kind of development model we have chosen, in which the use of such pesticides and highly toxic materials is allowed, or the character of science and technology as practiced in the country, or the suppression of vital medical and scientific information by Carbide assisted by our government."

Gokhale is an especially dramatic figure, in some ways a character out of a Greek tragedy. He wants his fellow Indians to know that his company has made every effort to demonstrate that the Carbide family cares very deeply about the plight of Bhopal's gas-affected survivors. Legally, he asserts blamelessness. He defends the management of the plant. Corporately, he stands together with the U.S. parent company. The trouble is that the parent isn't standing together with him. The managerial blame has been placed on UCIL by Carbide in Danbury. The parent firm believes that because mistakes were made in Bhopal, and because UCIL had full managerial responsibility, then the case should be shifted to India. "Fifty years of contributions to Indian society seem to have disappeared after this tragedy," Gokhale laments.

So although Carbide and UCIL both believe that the place of trial should be India, no one really wants a trial. All parties, except for various activist groups who want to punish Carbide, would prefer an out-of-court settlement. But that has complications, too, over the worth of an Indian life. Indian government sources close to negotiations say India would accept something less than $1 billion distributed by a formula that would ensure upfront costs and support to those suffering long-term pathologies. In addition, criminal charges against both companies would be dropped, those sources say.

There is a continuing vastness to the subject of Bhopal, one year after the calamity that so rocked the conscience of the chemical industry. The lesson then, as now, is that another Bhopal cannot be allowed to happen. Safety audits are the order of the day, in India and in the rest of the world. Workshops and symposia on industrial and community safety are densely scheduled. The chemical world has learned, because industrial disasters—so enormously wasteful of money, human energy, and long-built reputations—do teach. ☐

Reprints of this C&EN special report will be available at $5.00 per copy. For 10 or more copies, $3.00 per copy. Send requests to: Distribution, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. On orders of $20 or less, please send check or money order with request.

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1986 Pittsburgh Conference Program Page 53

DECEMBER 9, 1985

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VULCANUS II

OCEAN INCINERATION

Adrift in sea of controversy
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CHEMICAL & ENGINEERING
NEWS

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DECEMBER 9, 1985

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- **OSHA proposes health standards for benzene and formaldehyde in the workplace.** **Page 4**
- **Compromise bill on Superfund sent to House floor doesn't please chemical, oil companies.** **Page 5**
- **Artificial red blood cells that carry oxygen made by San Francisco researchers.** **Page 5**
- **PPG Industries slims down chemicals group through layoffs; closes production unit.** **Page 6**
- **Use of interleukin-2 to stimulate immune system cells to destroy tumor cells shows promise in fighting cancer.** **Page 6**

Cover: Vulcanus II burning hazardous wastes in North Sea

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Business

Third-quarter earnings of U.S. pharmaceutical companies rose strongly, mainly because of weaker U.S. dollar and cost controls. **Page 9**

Government

National Institutes of Health receives $5.5 billion for fiscal 1986, $3.1 billion of that for research project grants. **Page 12**

Science

Units combining microscopy and FTIR spectrophotometry get wider use in examining small samples or highly localized regions. **Page 15**

Amine phosphate molecule used to explore limits of hypervalency in nonmetallic elements in research at Iowa State University. **Page 16**

Technology

Modular units for thermal analysis, introduced by Du Pont, now allow chemists to choose desired level of system sophistication. **Page 19**

Books

"The Joy of Science: Excellence and Its Reward" explores some of the nontechnical aspects of success in science. **Page 44**

Meetings

Technical sessions, other information on Pittsburgh Conference, to be held in Atlantic City, N.J., March 10-14, 1986. **Page 53**

Special Report

Technology for ocean incineration of hazardous wastes is available but commercial operators, facing opposition of environmental activists, must await EPA regulations. **Page 24**

BENZENE, FORMALDEHYDE: Workplace exposure limits proposed

A logjam appears to have broken at the Occupational Safety & Health Administration. Last week the agency issued two new proposed standards for workplace exposure to benzene and formaldehyde. In the eight years since President Reagan took office, it has issued only five health-related standards.

For benzene, OSHA once again has proposed a permissible exposure limit of 1 ppm in air averaged over eight hours and an action level of 5 ppm. If workplace exposure is below the action level, employers do not have to meet the standard's proposed requirements for installation of engineering controls, provision of protective clothing and equipment, monitoring, or medical surveillance.

The four principal industrial sectors covered by the standard are petrochemicals, petroleum refining, coke and coal chemicals, and tire manufacturers. The agency estimates that some 270,000 workers are exposed to benzene and says that at the current 10-ppm exposure level, the chemical presents a risk of 44 to 156 excess deaths per 1000 employees. The proposed 1-ppm level is expected to reduce this risk about 90%. As a result, an estimated 822 lives would be saved over a working lifetime.

That estimate appears to meet the test set forth in a 1980 Supreme Court decision that overturned OSHA's first, 1978 attempt to lower benzene exposure to 1 ppm. In its decision, the court said the agency had to prove, based on substantial evidence, that exposure to a chemical poses a significant risk of substantial health impairment before acting to lower exposure to that chemical. Neither the Chemical Manufacturers Association nor the American Petroleum Institute, which were parties to the suit that resulted in the overturn of the first standard, was prepared to comment on the new one at press time.

OSHA says that because there is substantial controversy over formaldehyde's potential carcinogenicity to humans—the compound has been shown to cause nasal carcinomas in rats—it has proposed two regulatory alternatives. Under one, formaldehyde would be treated as a carcinogen. The exposure level would be lowered from the current 3 ppm to 1 ppm with an action level of 0.5 ppm with other requirements similar to those proposed for benzene.

Alternatively, the agency says it might simply lower the exposure level to 1.5 ppm if the record developed during the rule-making procedure indicates that the primary health concern is mucous membrane irritation and sensitization. OSHA estimates that some 1.3 million workers are exposed to formaldehyde. But fewer than half are exposed to levels above 0.5 ppm and even fewer, primarily in the wood finishing, plastics, and synthetic resins industries, to levels above 1.0 ppm.

OSHA has one proposal for benzene . . .

Exposure limit	
Current	10.0 ppm
Proposed	1.0 ppm
Action level	0.5 ppm
Workers exposed	270,000
Annual cost	$29 million

. . . but two options for formaldehyde

Exposure limit	
Current	3.0 ppm
Proposed	
Carcinogen	1.0 ppm
Irritant	1.5 ppm
Action level	
Carcinogen	0.5 ppm
Irritant	0.75 ppm
Workers exposed	1.3 million
Costs	
Carcinogen	
Capital	$57.8 million
Annual	$28.3 million
Irritant	
Capital	$38.9 million
Annual	$17.0 million

Ronald Lang of the Synthetic Organic Chemical Manufacturers Association says he is in general agreement with the approach OSHA is taking toward regulating formaldehyde in that it is looking at the most probable risk numbers rather than the worst-case scenario, as most federal agencies have done in the past.

However, labor unions that had sued the agency to force issuance of both standards, although pleased that the agency finally has done something, are very concerned because neither proposed standard contains the limits on short-term exposure levels that are present in the current standards for both chemicals. That means, they contend, that workers could be exposed to potentially lethal levels of the chemicals for short periods of time without any law's being violated.

OSHA had been ordered by the U.S. Court of Appeals for the District of Columbia to propose the formaldehyde standard by Dec. 3—it just met that deadline. And the agency was to appear in federal appeals court on Dec. 11 in a suit by the United Steel Workers seeking issuance of the benzene standard. Separate public hearings on both proposed standards, which likely will be published in the *Federal Register* this month, are expected to begin next March. □

U.S. Drug Firms' Profits Rose Strongly in Third Quarter

Helping bolster bottom line of companies, most of which rely heavily on sales abroad, are weaker U.S. dollar and continued cost controls

David Webber, C&EN New York

U.S. pharmaceutical companies, most of which sell a large percentage of their products abroad, for the past few years have attributed the moderate nature of their growth to the high value of the dollar. With regularity in recent quarters, solid sales increases when measured in local foreign currencies have shown up as small gains or even declines when translated into dollars. Now, the dollar has weakened a bit. At the same time, rigorous cost control measures implemented over the past two years continue to pay off.

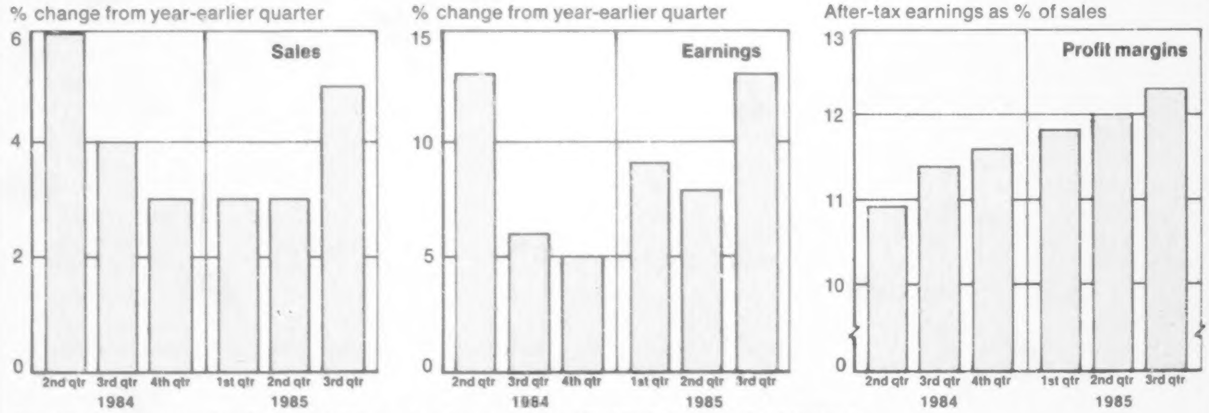
As a result, composite net income of a group of 16 major drug firms rose 13% in the third quarter compared with the same span a year earlier, the first time in five consecutive quarters they have turned in overall earnings growth in the double-digit range. Sales for the group rose a composite 5%, the highest gain in five quarters. And profitability (after-tax earnings as a percentage of sales), which has been growing steadily, climbed in the third quarter to 12.3% from 11.4% in third-quarter 1984.

The scale of earnings growth varied greatly throughout the group, but every firm except Avon Products, with a 16% decline, and Sterling Drug, with no change in net income, recorded an increase in the quarter. It was a good period, for example, for Upjohn, which raised its earnings 49% from the year-earlier quarter on a 9% sales increase. Pacing the gain was the company's human health care products and services sector, for which sales rose 10%. Agricultural sales were lifted 4% by strong seeds performance, which offset flat animal health products and sharply lower feed additive sales. Also in the third quarter, Upjohn completed the sale of its polymer chemical business to Dow Chemical. The deal not only provided Upjohn cash to retire some short-term debt but eliminated an operation that lost nearly $4 million after taxes in third-quarter 1984.

Becton Dickinson posted a 30% increase in net income on a 4% sales gain, leading the company to boost its quarterly common stock dividend 10% to 33 cents per share. Sales growth of 5% by the company's health care segment was partly offset by a 4% decline in the industrial safety products operation. The earnings exceeded the company's own expectations, largely the result of improved gross profit margins and better operating expense ratios.

"Overall, we are pleased with the results," says chief executive Wesley J. Howe. "Although our emphasis on expense reduction will continue, we are now giving increasing attention to sales growth."

Merck recorded a 13% jump in earnings despite flat sales in the quarter. But sales were flat largely because the company earlier this year divested Calgon Carbon and



Pharmaceutical industry 1985 third-quarter results

Note: All sales, earnings, and profit-margin statistics are based on combined results of the 16 companies listed on page 10.

Pharmaceutical profitability improved in third quarter

	THIRD-QUARTER 1985						NINE-MONTHS 1985					
	Sales	Earnings[a]	Change from 1984		Profit margin[b]		Sales	Earnings[a]	Change from 1984		Profit margin[b]	
	($ millions)		Sales	Earnings	1985	1984	($ millions)		Sales	Earnings	1985	1984
Abbott Labs	$ 822.7	$106.7	13%	17%	13.0%	12.5%	$2405.9	$323.9	7%	16%	13.5%	12.4%
American Home Products	1210.3	185.4	4	7	15.3	14.8	3530.8	533.4	4	9	15.1	14.5
Avon Products	707.0	25.4	−5	−16	3.6	4.1	2102.9	89.0	−8	−18	4.2	4.7
Baxter Travenol Labs	519.1	47.0	11	18	9.1	8.5	1516.3	129.4	13	6	8.5	9.1
Becton Dickinson	315.9	28.9	4	30	9.1	7.3	1089.3	91.2	11	25	8.4	7.4
Bristol-Myers	1172.5	149.9	10	12	12.8	12.6	3334.7	400.5	5	13	12.0	11.2
Lilly	787.9	122.1	11	9	15.5	15.7	2453.6	393.1	5	6	16.0	16.0
Merck	855.8	136.1	0	13	15.9	14.1	2589.5	405.5	0	7	15.7	14.5
Pfizer	1012.8	155.5	2	16	15.4	13.5	2966.6	440.4	2	16	14.8	13.1
A. H. Robins	189.0	17.8	20	8800	9.4	0.1	520.1	44.6	12	121	8.6	4.3
Schering-Plough	472.1	43.4	2	13	9.2	8.3	1438.7	149.3	1	7	10.4	9.8
SmithKline Beckman	820.7	131.6	9	2	16.0	17.2	2361.3	384.8	8	1	16.3	17.4
Squibb	522.7	72.5	6	14	13.9	12.9	1450.4	167.1	6	13	11.5	10.8
Sterling Drug	486.0	45.4	2	0	9.3	9.5	1355.4	110.4	−1	2	8.1	7.9
Upjohn	474.7	45.7	9	49	9.6	7.1	1494.3	152.9	4	5	10.2	10.1
Warner-Lambert	828.9	60.9	4	8	7.3	7.1	2434.4	187.6	3	9	7.7	7.3

a Excludes significant extraordinary and nonrecurring items. **b** After-tax earnings as a percentage of sales. **Note:** G. D. Searle & Co. formally merged into Monsanto Oct. 1, 1985, and has been removed from the list.

Baltimore Aircoil. "An improved product mix, the continuation of aggressive cost controls, and productivity improvements contributed to the income gains," says P. Roy Vagelos, chief executive of the company.

SmithKline Beckman, on the other hand, posted a net income gain of just 2% on a sales increase of 9% during the third quarter. In the therapeutics area, sales of its ethical pharmaceutical products segment increased 5% to $399 million, and sales for eye and skin care products jumped 27% to $74 million. But sales were nearly even with the year-earlier period for both consumer and animal health care products, leaving the entire therapeutics area with a 7% sales rise. The diagnostic/analytical area reported a sales gain of 16%, paced by a 57% jump in sales of clinical laboratory services.

Just before Thanksgiving, the company announced that in a cost-cutting measure it was offering special early retirement incentives to about 700 employees. "The program is part of our effort to adjust our operations so that we can continue to compete successfully in a changing and challenging marketplace," explains Henry Wendt, chief executive officer of SmithKline Beckman.

Even more drastic action to cut costs is being taken by Warner-Lambert, which recorded an 8% earnings increase on a 4% rise in sales in third-quarter 1985. To shave $30 million off worldwide costs, the company is, at a charge of $550 million against fourth-quarter earnings, offering special early retirement incentives, putting all its health technologies businesses on the block, and consolidating other selected operations. The divestitures will allow the firm to concentrate on its activities in pharmaceuticals and consumer products.

In the third quarter, sales for Warner-Lambert's health care technologies businesses—which contribute only about 1% to annual earnings—mostly declined. On the other hand, sales of pharmaceuticals through the Parke-Davis unit increased 17%, and sales of nonprescription drugs climbed 15%.

Avon's 16% earnings slump was caused by the continued poor performance of its beauty business. The decline more than offset improved operating results in the firm's other divisions: Mallinckrodt, Foster Medical, and Direct Response. "The Avon division's U.S. strategies are about three months behind where we wanted them to be," concedes chief executive Hicks B. Waldron.

At Baxter Travenol Laboratories, third-quarter net income jumped 18% on an 11% sales increase despite lower average selling prices for the company's products. "Our operating performance continues to meet expectations," says Vernon R. Loucks Jr., president and chief executive officer of the company. "Results for the third quarter reflect positive contributions from practically every area of the company. We are encouraged by the progress we are making despite the continued cost containment efforts of health care payers, which are resulting in lower levels of hospital activities."

Continuing its run of strong quarters, Abbott Laboratories reported record results: Earnings rose 17% on a sales increase of 13%. Chief executive officer Robert A. Schoellhorn attributes the improved earnings to higher volume, continued productivity increases, improved product mix, and a lower tax rate.

"Our performance further confirms something we have pointed out for many years—that there are major advantages to our diversification within health care," he says. "Equally important to our success is that Abbott's broad range of products and services help health care providers meet the growing challenges of cost containment." □

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Advances in materials highlight battery developments
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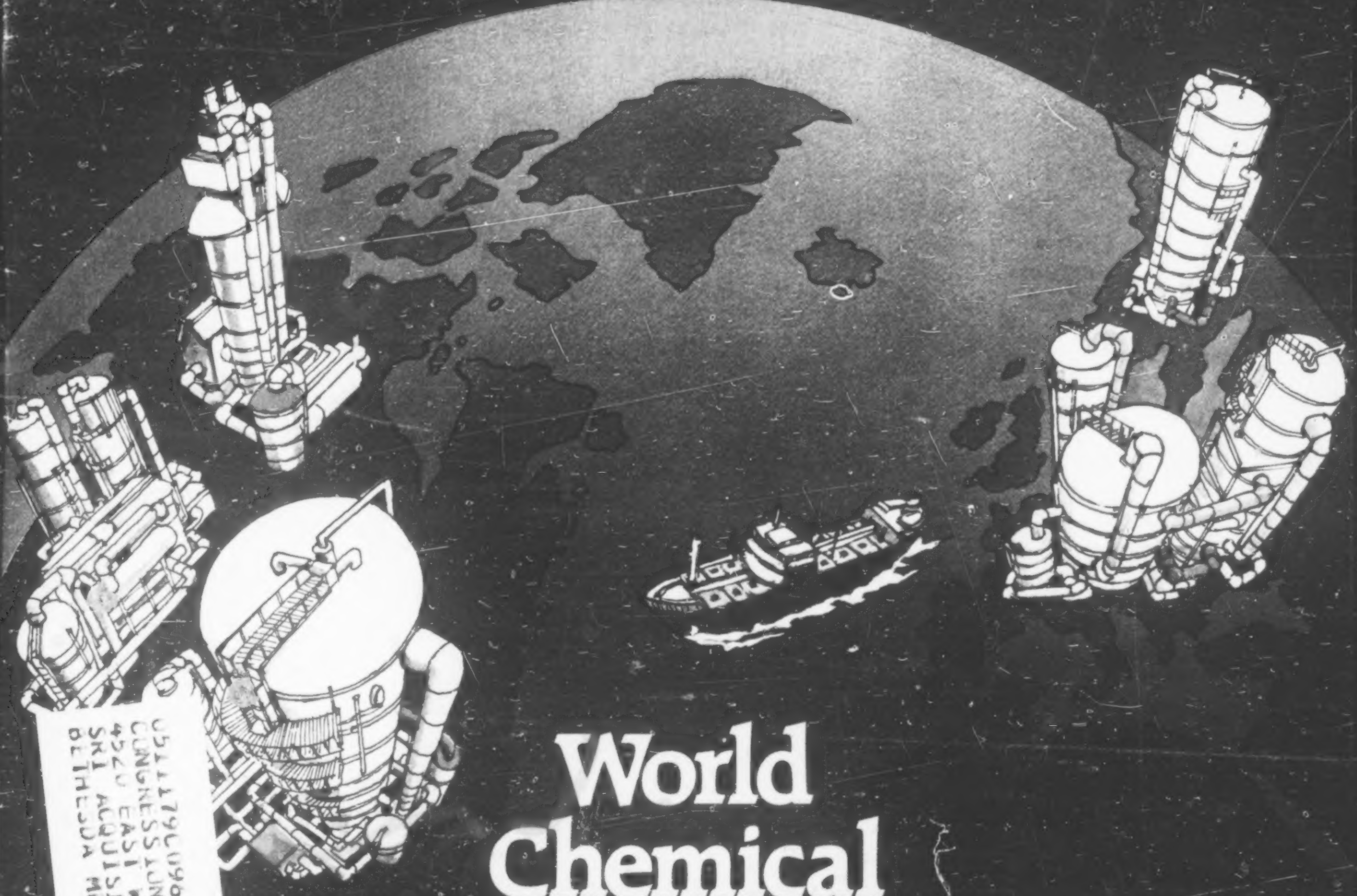

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World Chemical Outlook

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CHEMICAL & ENGINEERING NEWS

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DECEMBER 16, 1985

News of the Week

- **GAF desires merger with Union Carbide. Page 4**
- **House-passed Superfund bill puts financing burden on oil and chemical industries. Page 5**
- **Paul V. Smith Jr. elected to third successive term as chairman of ACS Board. Page 5**
- **Bachelor's degree graduates in science and engineering face a smaller job market this spring, survey indicates. Page 6**
- **W. R. Grace to buy back 26% of its common stock from West German bank, sell its retail group to help finance repurchase. Page 6**

Business

Makers of large-volume solvents plagued by rise in imports, slump in demand; no new markets are on the horizon. **Page 9**

Government

Agreement on how a toxic wastes landfill in Niagara, N.Y., will be cleaned up has been reached by Occidental Chemical, the state of New York, and the Environmental Protection Agency. **Page 14**

Science

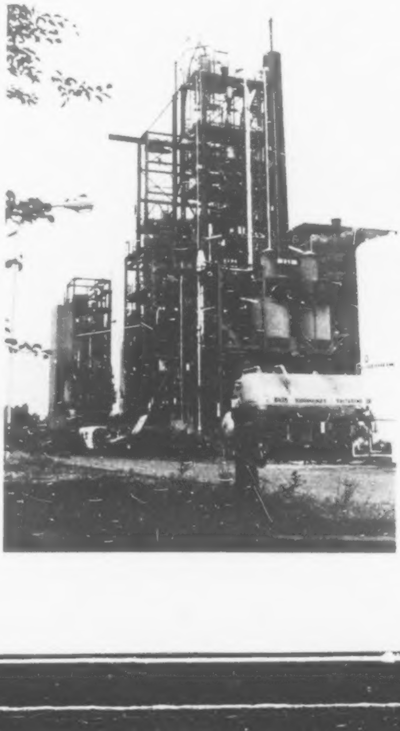
Why cisplatin is effective against tumors whereas its trans isomer is not is attributed to the fact that the cis-isomer DNA adduct is not easily recognized or repaired by the cell, researchers find. **Page 20**

Technology

Improved ceramics for sodium/sulfide batteries and a stabilized iron disulfide electrode for lithium/iron disulfide cell are among recent developments in battery materials. **Page 23**

Books

"The Gene Factory" by John Elkington provides an overview of the birth and rise of the biotechnology industry. **Page 50**



Special Report

Worldwide, chemical industry growth is sluggish, competition grows fiercer, and attempts to trim costs and improve efficiency are the order of the day. Page 28

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Major-Volume Solvents Shift To Lower Production Rates

Producers of acetone, synthetic ethanol, and methylene chloride, beset by rising imports and weakening demands, face long slump

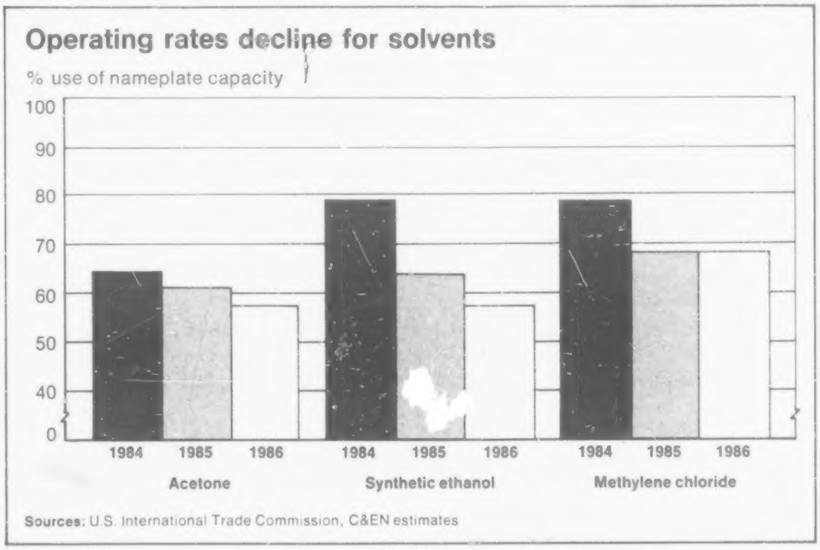
Bruce F. Greek, C&EN Houston

Producers of three of the largest-volume organic chemicals used mainly as solvents—acetone, synthetic ethanol, and methylene chloride—have little to be happy about. For acetone, no new markets are ahead that could lead to more production without dependence on coproduct phenol. For ethanol, imports are taking larger and larger shares of its markets. Methylene chloride faces weakening demand for many of its larger uses with no replacements by new or smaller uses on the horizon. And it faces possible environmental pressures.

Acetone differs from ethanol and methylene chloride because of its status as a coproduct in the manufacture of phenol. Unless the demand for acetone rises far more than is now forecast by industry sources and pushes selling prices higher than is expected, little acetone will be made for its own sake for a long time. What is produced will be as a by-product of phenol. Hence the long-term outlook for acetone depends on demand for phenol, which, in turn, depends on construction. The small amount of acetone capacity that is based on isopropyl alcohol consists of relatively small and old plants that probably would be uneconomical to operate if they did not have captive demands.

Key Chemicals

Some newer uses are helping demand for phenol, but construction still dominates the end uses, leaving acetone's future dependent on construction. Housing, which comprises the majority of phenol's consumption in construction, has grown little if at all this year, and may even be slightly down from last year. Prospects for 1986 are similar.


Operating rates decline for solvents

% use of nameplate capacity

Sources: U.S. International Trade Commission, C&EN estimates

Output of synthetic ethanol has been subjected to severe pressure as a result of the rapid rise in imports during 1985. Little doubt exists that imports from Saudi Arabia will at least hold steady, and possibly rise. Fermentation ethanol also will continue to be imported in volume over the longer term. Although most imported fermentation ethanol is aimed at the gasoline octane additive market, some will ease more into uses as chemical intermediates and less critical solvents.

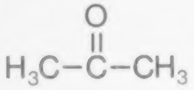
In total ethanol consumption, synthetic material has become a relatively small player, especially if fuel ethanol is included in the total. Synthetic's position likely will continue to decline to the point where synthetic ethanol occupies only the critical solvent markets. If a way can be found to clean up fermentation ethanol sufficiently, then synthetic ethanol production might be ended.

Methylene chloride's problem may be its near total success in capturing markets from other solvents. The result of its success is a rise in its dominance in end uses that are predicted to have no growth or a small long-term decline. Hence, methylene chloride now has no place to expand. Most other sizable markets for methylene chloride are influenced by the declining steel fabrication industries. All of these end uses pushed output of methylene chloride up during the 1970s. For the rest of the 1980s, however, a reversal in output and possible capacity declines seem to be in store.

For details of the near-term outlook for these solvents, please see the following pages.

Key Chemicals

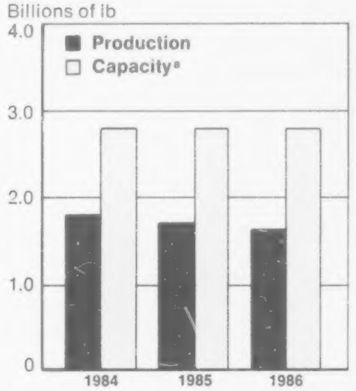
Acetone



$H_3C-\overset{\overset{O}{\|}}{C}-CH_3$

- ***Production off a bit***
- ***Capacity on hold***
- ***Prices steady***

PRODUCTION/CAPACITY



a First quarter, excludes about 300 million lb "on standby."

MAJOR PRODUCERS

Allied-Signal, Dow, General Electric, Shell, USS Chemicals

HOW MADE

Coproduction with phenol by oxidation of cumene (isopropyl benzene); dehydrogenation of isopropyl alcohol

MAJOR DERIVATIVES

Methyl and other methacrylates 35%, bisphenol A 10%, methyl isobutyl ketone 10%

MAJOR END USES

Solvents, alone or as derivatives, 50%, fabricated plastics 35%

FOREIGN TRADE

Exports—more than 100 million lb; imports—about 100 million lb

PRICE

About 25 cents per lb

Production of acetone, one of the few major-volume organic chemicals heavily dependent on demand for a coproduct, in this case phenol, is continuing to slide. Acetone output will drop about 5% both this year and next, hitting 1.7 billion lb in 1985 and 1.6 billion lb in 1986; in 1984 production was more than 1.8 billion lb.

About 85% of U.S. acetone capacity is based on oxidation of cumene (isopropyl benzene), which also produces phenol. Demand for phenol depends on demand for housing that requires plywood and particle board as construction materials. Phenol's largest use is in adhesives for plywood and binders for particle board. Both of these are made by means of reactions with formaldehyde.

Two views on the outlook for housing are relevant to the outlook for acetone. One view holds that lower interest rates are causing a decline in the inventory of existing houses and, beginning in the spring of 1986, will cause an increase in demand for new housing. The other view is that changes in household formation, real income, and construction costs offset the effects of lower interest rates and will cause a flat to slightly reduced demand for new housing.

Both views suggest that plywood inventories will change. For example, as housing starts remained flat or declined during the second half of 1985, plywood inventories were cut for a variety of reasons, including savings in the cost of interest. Now, with inventories relatively low, prediction of an upswing in housing and to some extent in commercial construction in 1986 could result in an increase in inventories. Inventory building would push phenol demand, and in turn acetone production, more than actual growth in construction would.

Some analysts argue, however, that there will be no significant rise in housing construction in the first half of 1986. If this happens, phenol demand could grow little or decline. Acetone production would then follow the same pattern as in 1985.

For marketers of acetone, the situation isn't necessarily bad. Because output was somewhat limited during 1985, prices improved. But late this year, prices, as usual, weakened, as demand for acrylates and solvents slowed with industrial production. Next year, if production also slows another 5% or so (100 million lb), prices might improve more than in 1985, as demand in various uses recovers.

The supply of acetone, however, will not get so tight that prices could rise quickly. Inventories and exports could be reduced to meet demand. Imports also could be increased. Those units that make acetone from isopropyl alcohol could be operated at higher rates to provide more product for the merchant market in contrast to supplying largely captive uses as they do at present.

More than a third of acetone consumed in the U.S. goes to make various methacrylates, about 80% of which is methyl methacrylate. Those methacrylates go into a number of fabricated polymer products such as sheets, coatings, fibers, and molded and extruded items. Some threat to acetone as the raw material for acrylates could come from isobutylene. The threat seems to be delayed now by the demand for isobutylene to make high-octane components for gasoline. This demand is spurred by the decrease in the amounts of lead alkyls allowed in gasoline. Demand for acetone to make acrylates will grow about 5% in 1986.

Other uses of acetone—for making bisphenol A and solvents such as methyl isobutyl ketone, methyl isobutyl carbinol, and aldol condensation products, and as a solvent itself—will increase more slowly, generally close to 2% per year. Because such uses are so large, the 1986 growth in demand for acetone will be about 2% overall. That growth probably can be handled without undue stress on the industry, even with an expected decline in production.

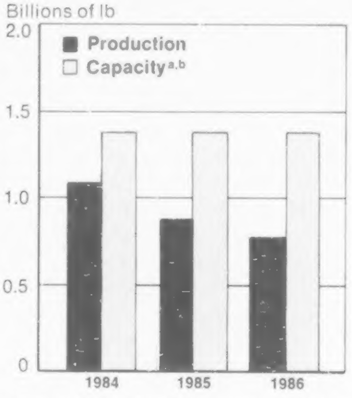
Key Chemicals

CH_3CH_2OH

Ethanol

- ***Production off steeply***
- ***Capacity on hold***
- ***Prices level***

PRODUCTION/CAPACITY



a Synthetic only. **b** First quarter, excludes capacity "on standby."

MAJOR PRODUCERS

Eastman Chemical, U.S.I. Chemicals, Union Carbide

HOW MADE

Synthetic—direct hydration of ethylene; otherwise fermentation

MAJOR DERIVATIVES

Acetic acid (vinegar) 10%, esters 10%, ethers 10%

MAJOR END USES

Solvents 55% (85% including derivatives), food 10%

FOREIGN TRADE

Exports—declining to less than 10 million lb; imports—rising to more than 500 million lb

PRICE

$1.80 per gal

Synthetic ethanol production (excluding beverage alcohol), which has been declining rapidly in recent years, is expected to continue its slump through 1986 and possibly later. Any reversal of this situation will depend on a tight control of imports. This year imports of both synthetic and fermentation ethanol likely were several times U.S. output.

The import problem is far worse for producers of fermentation ethanol, which is used in gasoline mixtures for motor fuel, than it is for producers of synthetic ethanol. However, in 1985 a considerable—but impossible to estimate accurately—quantity of synthetic ethanol arrived from Saudi Arabia.

Some imported fermentation ethanol goes to uses formerly supplied by synthetic ethanol, including uses in some solvents and as intermediates for various chemicals. Rising imports of both fermentation and synthetic ethanol caused this year's rather steep decline in output of synthetic ethanol. Production in 1985 will do well to reach 900 million lb, down about 20% from 1984 output of more than 1.1 billion lb. For the first three quarters of 1985, preliminary figures show production of about 730 million lb on an annualized basis. Often, however, a surge in synthetic ethanol production occurs during the fourth quarter. This makes a higher annual total likely.

The decline in production of synthetic ethanol forecast for 1986 will be about half that expected for 1985. Next year's output could total 800 million lb, but probably will be less, if imports continue at current levels or rise slightly.

Falling capacity utilization is hurting the three synthetic ethanol producers. For 1985, the average operating rate is estimated to be less than 65% of nameplate capacity, and for 1986, it is predicted to be less than 60%. This downward trend indicates that some capacity might be shut down. However, a number of producers have captive uses for their ethanol, allowing them to keep units operating. But, the make-or-buy decision looms over producers, especially if they have a more profitable use for the ethylene consumed in the ethanol.

Some synthetic ethanol will continue to be needed for certain cosmetic and pharmaceutical solvents in which odor is critically important. Slightly more than half of U.S. synthetic ethanol is used as a solvent, and, of this, about 30% goes into cosmetics. Fashion influences make demand forecasts difficult in cosmetics. Over the near term, growth is predicted to be modest—less than 5% annually.

Other solvent uses of ethanol such as in coatings and inks are under pressure from lower-cost imported material. In certain proprietary uses, only synthetic ethanol will do the job, but in most uses, fermentation ethanol is acceptable. In some applications, especially coatings, isopropyl alcohol also provides competition. Growth in these other solvent applications will remain modest; for most it will be less than 5% annually.

Ethanol is used to make a wide variety of chemicals, with ethyl acrylate, vinegar, various glycol ethers, ethylamines, and ethyl acetate ranking among the larger uses. Each of these products has various uses as well, of which none have strong growth prospects. Because of the inroads of fermentation alcohol, as a group the various chemical uses of synthetic ethanol probably will show a small decline next year, as they are showing in 1985. Use in glycol ethers is especially vulnerable owing to concern over their possible toxicity.

The small growth expected in the aggregate of ethanol's chemical and solvent end uses will be obscured by the rise in its consumption as a motor fuel. If imports of ethanol for fuel use continue to rise in 1986, they still will be diverted into nonfuel uses, which is what caused the declines in production of synthetic ethanol in 1985 and is expected to cause them in 1986.

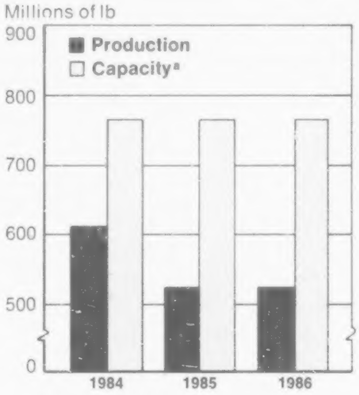
Key Chemicals

CH_2Cl_2

Methylene chloride

- ***Production to hold***
- ***Capacity variable***
- ***Prices steady***

PRODUCTION/CAPACITY



a First quarter, maximum (actual capacity varies with product mix of chloromethanes).

MAJOR PRODUCERS

Diamond Shamrock, Dow, LCP Chemical, Vulcan

HOW MADE

Chlorination of methane; hydrochlorination of methanol, then chlorination of methyl chloride

MAJOR END USES

Paint remover 30%, aerosols 20%, degreasing agent 10%, chemicals manufacturing 10%, blowing agent 5%

FOREIGN TRADE

Exports—about 50 million lb; imports—about 50 million lb

PRICE

About 35 cents per lb

Methylene chloride producers have cut output drastically in 1985, and prospects for improvement in 1986 are slim. Compounding the problem, the Environmental Protection Agency has begun its long-awaited study on the possible risks of cancer from exposure to methylene chloride, which is used largely as a solvent.

Current estimates put production of methylene chloride in 1985 at about 520 million lb, or slightly less. That figure is about 15% less than last year's output of 607 million lb estimated by the U.S. International Trade Commission. However, the annualized 1985 production for the first three quarters totals 510 million lb. If the final 1985 estimate is increased as much as was the final 1984 figure over the preliminary estimate, then 1985 production could be as much as 550 million lb. Thus, output would be down only about 10% from 1984.

Production of all four chloromethanes—methylene chloride, methyl chloride, chloroform, and carbon tetrachloride—is down, but not uniformly, from levels in 1984 when recovery from the recession reached its peak. The reason for irregular changes in output is the flexibility that manufacturers have in running plants to make whichever chloromethane is most in demand. Capacity estimates for methylene chloride are the maximum that can be produced, partly at the expense of output of other chloromethanes. Based on this maximum capacity, the 1985 average operating rate for methylene chloride plants is 68% of nameplate.

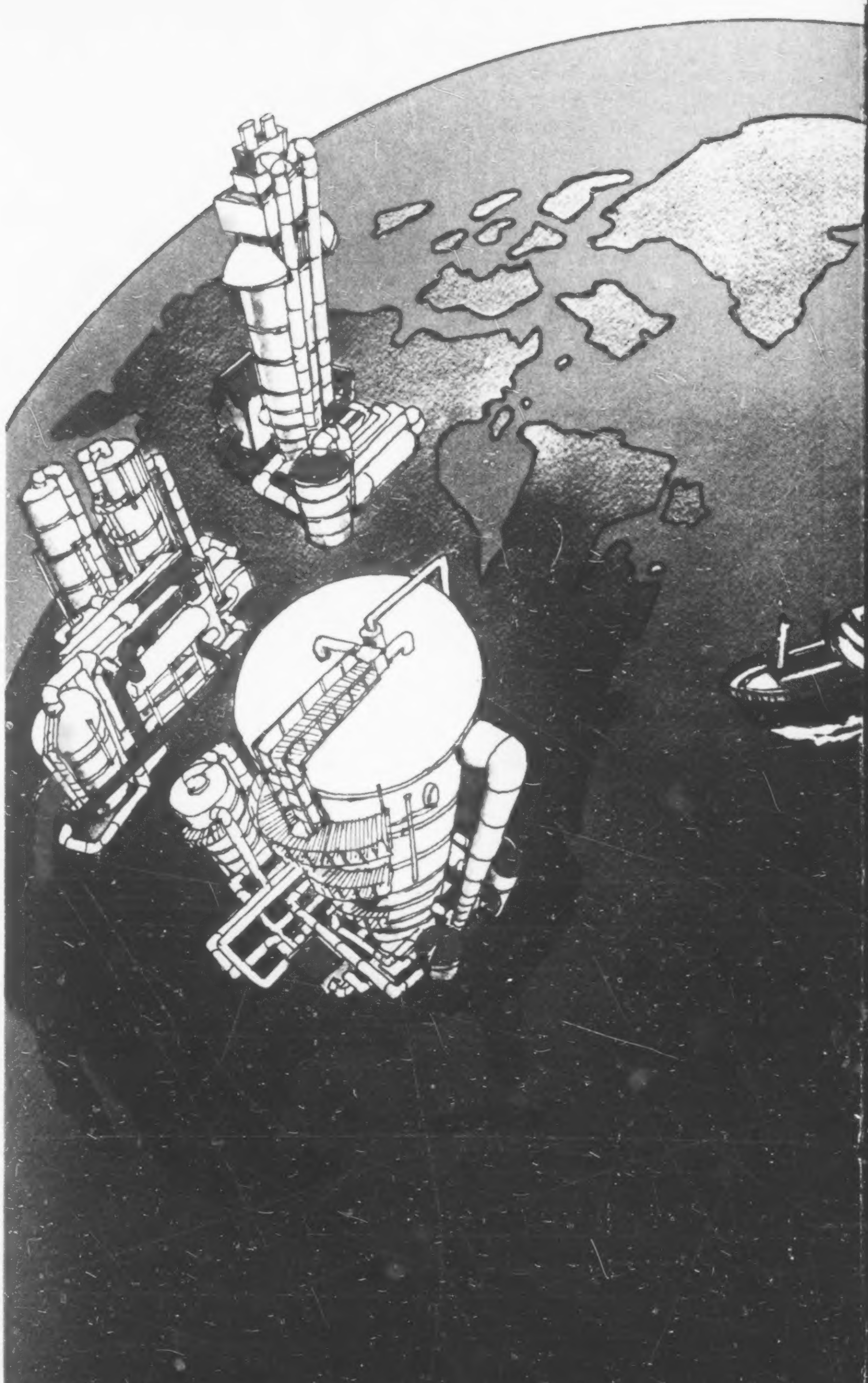
Manufacturers of methylene chloride would like to increase output this year and next to offset anticipated lower production and sales of chloroform. This decline in sales will result from the modification of a Du Pont chloroform plant that will make Du Pont nearly self-sufficient in its supply of raw material to make dichlorodifluoromethane, used as a refrigerant and in manufacturing fluoropolymers.

Demand for methylene chloride is forecast to remain nearly stagnant in 1986. The end uses are expanding very little and may well shrink, depending on how the public views the results of the EPA toxicity study. Most uses of methylene chloride depend on its solvent properties; relatively small quantities are used as chemical intermediates.

The largest solvent use of methylene chloride is in paint removers. For several years this use grew rapidly as methylene chloride replaced other solvents that came under air pollution control regulations. However, growth has abated recently because demand for paint removers is rising slowly and capture of the markets held by other, older paint remover solvents is almost complete. If more concern develops over toxicity, use in paint removers could decline steeply after 1986.

The second largest use of methylene chloride, that as a propellant in aerosol preparations, also has grown little. Methylene chloride took over much of the market from fluorocarbon propellants because of concern about damage to the atmospheric ozone layer. Methylene chloride apparently causes little damage to the ozone layer because it decomposes relatively rapidly in air. For the near term, growth in this use of methylene chloride will follow closely that of the population and will vary as a result of changes in use of hair sprays and other aerosol products.

The other uses of methylene chloride also rely on its solvent properties. Those include industrial cleansers and degreasers, which depend on trends in industrial operations. For example, the shift to less metal processing in making automobiles and other durable goods tends to reduce demand for methylene chloride. A host of small solvent uses account for a large part of consumption, but none of these are increasing fast enough to help much in stemming the general decline in use of methylene chloride.

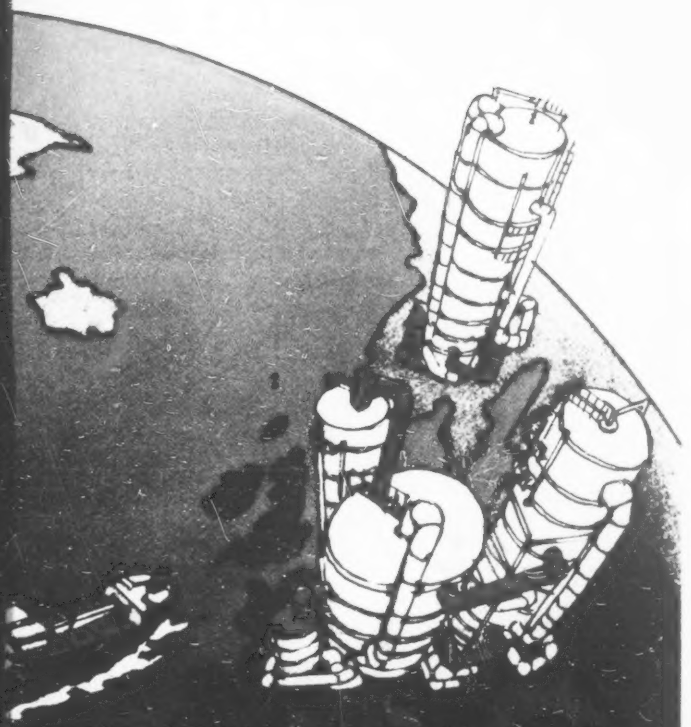


With economic growth turning sluggish in much of the industrialized world, growth in demand for chemicals also is slackening. Chemical producers, as a result, are being forced to slug it out in increasingly competitive markets. Many are being bloodied in the process.

North America is a good example. In the U.S., growth in chemical output has been just about negligible recently. Selling prices are under pressure. Sales are flat. And profits have nosedived. North of the border, Canadian chemical firms likewise are finding earnings unsatisfactory; some domestic markets are anemic and competition for foreign customers is more heated.

Japanese chemical companies, despite a year of strong sales and profits, face similar concerns. A less robust domestic economy coupled with increasing difficulties in maintaining offshore sales suggests that business may soon weaken. In Western Europe, too, business has been relatively healthy. But the European growth pace also is slowing, making the fight for market share more intense.

Both in the U.S. and elsewhere, the chemical industry has been undergoing a massive restructuring. Excess capacity has been shut down and low-profit operations spun off as the industry strives to trim costs and improve efficiency. But the payoff is still uncertain. Competition for worldwide market survival at the same time is heightening.



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United States

Profits slump as demand for chemicals stagnates

Continued economic growth, a weaker dollar, and corporate restructuring may bolster chemical firms' earnings next year

David M. Kiefer, C&EN Washington

The U.S. economy has lumbered through 1985 like a rather weary, sluggish giant—fundamentally strong, but not moving forward very fast. And the U.S. chemical industry, as a consequence, has been sorely beset.

Gross national product this year, after adjustment for price changes, is expected to be up only 2 to 3%, with most of the growth coming during the final six months after an anemic 1% growth in 1985's first half. Industrial production likewise is running only about 2% ahead of a year ago. Business continues to be plagued by a widening trade deficit that this year will suck $125 billion worth of demand out of the U.S. economy. And the astronomical $212 billion deficit in the federal budget (for fiscal 1985) has eroded business and consumer confidence.

On the plus side, however, inflation seems firmly in check. Consumer prices now are merely 3% above the year-earlier level, and wholesale prices are essentially unchanged. Inflation has not been so low for any extended period in nearly 20 years. Interest rates, too, have fallen. They are at the lowest level of the past five years or more, although in real terms—measured against inflation—they remain disturbingly high.

Nevertheless, the economic climate this year has not been conducive to the health of chemical producers. For the industry as a whole, growth in output has been almost nil. Production of industrial chemicals and synthetic materials, overall, was up less than 3% this past fall from the fall of 1984.

Plastics have set the pace; output will be up 5% or more, although polyvinyl chloride is a notable exception. Elsewhere, however, disappointment is widespread. Production of most of the commodity inorganic and organic chemicals, as well as the big-volume synthetic fibers other than polypropylene, has failed to match 1984 volume.

Selling prices have been similarly disappointing, especially for fertilizers, synthetic fibers, and some plastics. Slack demand, chronic excess capacity, and competition from foreign-made material have kept prices under pressure for more than three years. For all of 1985, industrial chemicals sold at prices that averaged about 1% less than in 1984, although they have recovered slightly as the year closes.

Sales, too, have been flat for producers of industrial chemicals and synthetic materials. During the first half of the year, in fact, sales trailed those of the like 1984 period about 5%. Year-to-year comparisons will be looking a bit better for the second half, if only because sales were far from robust late last year. For 1985 as a whole, though, sales will be about equal to, or a little behind, last year's total.

Worst of all, however, for the industrial chemical industry, profits have been slumping for more than a year. Through this year's first nine months, despite lower energy costs and massive efforts by chemical companies to control operating costs, net income was down more than 20%. The current quarter probably will not look so bad, again because the comparison will be made against the relatively weak final quarter of 1984. Even so, profits for all of 1985 will lag those of 1984 20%, if not more. That's a far poorer showing than had been expected by most people in the industry. A year ago, the consensus was that earnings probably would rise as much as 10 to 15% this year.

The real level of earnings for 1985 is being clouded by the unprecedented corporate restructuring that has swept the chemical industry. Companies have been shucking off unwanted businessess and trimming their staffs for several years now. But this year, they have been selling or shuttering inefficient, obsolete, and ill-fitting operations and cutting back on personnel through attrition, early retirement, and outright firings to an extent unmatched previously. The efforts reflect a growing long-range interest by many firms to shift the focus of their business from commodity products to specialty chemicals, where competition may be less intense and profitability easier to maintain. The result has been a wave of huge write-offs and other charges that are chopping into 1985 income.

The chemical industry's prospects for the year ahead again will depend on the trend of the nation's overall economy.

The consensus now is that gross national product again will rise slowly but steadily throughout the next 12 months, although unlike this year the greatest growth probably will take place during 1986's first half. For all of 1986, GNP generally is expected to be 2.5 to 4% higher than this year's total. That would be a slight improvement over the growth that is occurring this year.

As 1985 winds down, in fact, the nation's economy seems surprisingly free of obvious stresses. Inflation remains comfortably moderate, with consumer prices likely to rise only a bit faster next year than they did during 1985, and energy costs trending lower. A weakening dollar, meanwhile, may well stem the inflow of foreign-made products. Interest rates, although always difficult to forecast, probably will change little in the year ahead after having dropped markedly from their lofty levels of early this year. Finally, consumers, whose incomes are rising, still appear to be in a free-spending mood.

All this should create a favorable market climate for vendors of chemicals. But in the final analysis, the health of the chemical industry is linked to several key markets, for some of which the outlook is at least somewhat cloudy.

Bumper crops and lower sales abroad have depressed prices for farm products, so that farmers' income is down and their heavy load of debt has become ever more burdensome. As a result, sales of both fertilizers and pesticides have been hobbled. And even though lower feedstock costs have eased the pain somewhat, fertilizer prices are severely depressed. The agricultural chemicals business may be no worse next year, but there still is no convincing evidence that it will be significantly better, either, especially since farmers likely will be planting fewer acres with wheat, corn, and other grains.

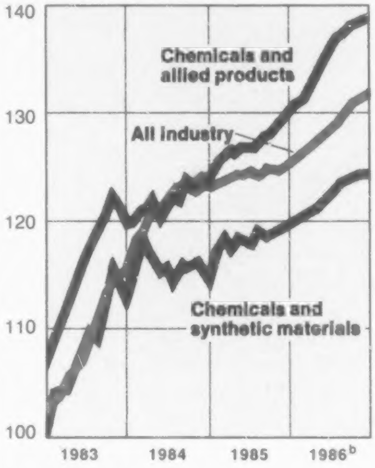
The automobile industry, a big consumer of chemical products, has had an up-and-down year in 1985. Sales were strong when spurred by discount financing programs and rebates, but slumped when such incentives were lifted. Meanwhile, imports have been winning a bigger share of the U.S. market since import quotas on Japanese cars were eased. Foreign cars now have captured about a third of U.S. auto sales.

This year, about 8.2 million cars are being produced in U.S. factories, up about 5% from 1984 to the highest level since 1979's 8.4 million. Total sales of cars this year will be close to 11 million.

Next year, sales most likely will taper off moderately. Ford Motor president Harold A. Poling, for example, estimates that sales will fall to 10.4 million cars, although other forecasters look for a higher total. In any event, imports probably will take a still bigger piece of the total market. That means that U.S. production is likely to skid to 7.6 million vehicles, down 7%. And that, in turn, is no small loss for U.S. chemical producers.

Chemical production will edge higher in 1986 . . .

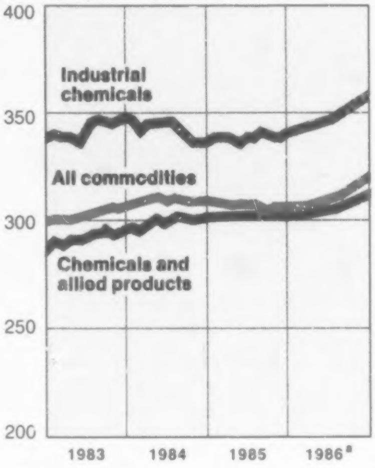
Industrial production index,[a] 1967=100



a Seasonally adjusted. b C&EN estimates.
Source: Federal Reserve Board

. . . while selling prices strengthen a bit . . .

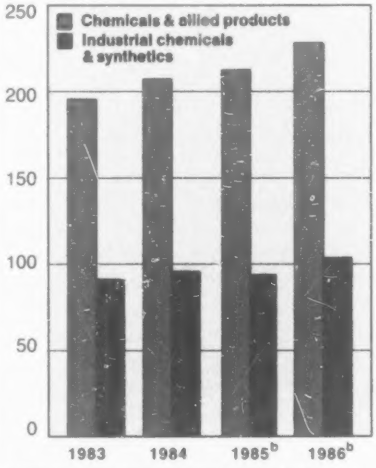
Producer price index, 1967=100



a C&EN estimates.
Source: Bureau of Labor Statistics

. . . industry sales advance moderately . . .

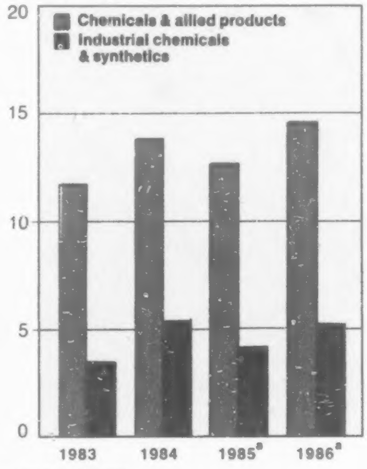
Net sales,[a] $ billions



a Excludes sales of foreign subsidiaries. b C&EN estimates. **Source:** Bureau of the Census

. . . and profits recover from this year's slump

Net income, $ billions



a C&EN estimates.
Source: Bureau of the Census

Housing, another big market for plastics, coatings, and fibers, also is an uncertainty. Lower interest rates on mortgages might be expected to generate higher demand for new houses. And mortgage rates have come down nearly two percentage points in the past 12 months to the lowest level in six years. Even so, home building remains in the doldrums. This year, housing starts will total between 1.7 million and 1.8 million, essentially unchanged from 1984. In part, the reason is that although mortgage rates have fallen, so has inflation. Therefore, the real cost of interest is still high enough to dampen demand. Recent overbuilding, meanwhile, has created a glut of apartments in many areas. The upshot is that housing is a market that is likely to expand next year, but not by much.

Two important markets for specialty chemicals that have been hard hit during 1985 are oil production and refining and semiconductors and other electronic products. The latter may be poised for a rebound, but the former remains depressed.

The softening of the U.S. dollar will have a broadly favorable impact on demand for chemicals. As the value of the dollar rocketed during the past five years, exports of chemicals of all types expanded less than 10%, but chemical imports climbed nearly 70%. But it is not just in direct trade in chemicals where a strong dollar has undercut demand for U.S.-made chemicals. The chemical content of imported clothing, electronic equipment, cars, and other manufactured goods also has eroded domestic chemical sales. The slump in production of fibers, for example, results in part from the fact that fiber imports are up about 10% this year. Even more of a factor, however, is the sharp increase in imports of foreign-made apparel and other textile products. Similarly, lackluster sales of agricultural chemicals can be blamed in part on lower sales of U.S. farm products abroad as well as on reduced exports of the chemicals themselves.

The most immediate effect of the weakening of the dollar will be on chemical companies with large overseas operations. They will be able to translate their foreign sales and earnings into U.S. dollars on more favorable terms. The full impact of the dollar's decline, however, probably will not materialize until mid-1986 or later. By then, the price advantage now enjoyed by foreign-made chemicals may have eased enough to make U.S.-produced chemicals more competitive. But many of the inroads made by foreign producers, both in domestic and international markets, in recent years are likely to be permanent.

Thus prospects for the chemical industry are far from clear-cut. Foreign business will be more profitable, in terms of dollars. The industry's costly restructuring probably is still incomplete; even the companies that took the biggest charges this year may find more assets to write down in the next year or two. Nevertheless, restructuring is likely to be a considerably smaller cost factor in 1986. Meanwhile, the cost savings and enhanced profitability stemming from the restructuring already completed can be expected to have a favorable impact on next year's earnings statements.

Moderate growth next year in the overall economy points to moderate growth for chemicals, as well. Production of industrial chemicals and synthetics, for example, probably will rise at least 3 to 4%. Recent price trends suggest, too, that the industry will benefit to a small extent from a firmer pricing structure. Sales, as a consequence, probably will be 5 to 7% higher.

Profitability, moreover, may be quite significantly enhanced. Lower feedstock costs, lower personnel expenses, and the shutdown of unprofitable operations all bode well for the industry. The upshot is that a rebound in earnings for producers of basic chemicals and synthetic materials of 20 to 25% from this year's depressed results would not be surprising. Even with that strong a showing, however, profits will not be so high as they were in 1984—or, for that matter, in 1981. □

Output of chemicals, generally down this year, will be up slightly in 1986

	1983	1984	1985	1986
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	14,072	16,192	16,450	16,200
Chlorine gas	9,960	10,724	10,600	10,800
Hydrochloric acid	2,608	2,866	2,800	2,900
Nitric acid	6,768	8,041	7,900	8,000
Oxygen, billions of cu ft	343	375	375	400
Phosphoric acid	9,767	11,111	10,800	11,100
Sodium hydroxide	10,230	11,224	10,800	11,100
Sulfuric acid	37,459	41,802	40,100	41,500
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	2,807	2,619	2,850	3,000
Acetone	1,859	1,862	1,800	1,900
Acrylonitrile	2,146	2,219	2,300	2,400
Benzene, millions of gal	1,233	1,318	1,400	1,500
Butadiene	2,353	2,827	2,700	2,800
Cumene	3,345	3,754	3,800	4,000
Cyclohexane	1,656	1,994	1,700	2,000
Ethylene	28,680	31,383	30,700	32,200
Ethylene glycol	4,425	4,842	4,600	4,800
Formaldehyde	5,465	5,815	5,800	6,000
Methanol	7,982	8,186	6,600	8,000
Phenol	2,638	2,889	2,800	3,000
Phthalic anhydride	838	870	850	900
Propylene	13,959	15,559	15,400	16,200
Styrene	6,802	7,709	7,500	7,900
***o*-Xylene**	781	688	690	740
***p*-Xylene**	4,114	4,264	4,600	4,800
PLASTICS				
Millions of lb				
Polyethylene, high density	5,689	6,085	6,650	6,950
Polyethylene, low density	8,041	8,415	8,800	9,100
Polypropylene	4,433	4,940	5,150	5,400
Polystyrene	3,570	3,838	4,050	4,200
Polyvinyl chloride	6,067	6,760	6,500	6,700
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	679	671	630	620
Nylon	2,419	2,412	2,330	2,400
Olefin and vinyon	906	997	1,200	1,280
Polyester	3,544	3,392	3,340	3,400

Sources: Bureau of the Census, International Trade Commission, Society of the Plastics Industry's Committee on Resins Statistics, Textile Economics Bureau, C&EN estimates (for 1985 and 1986)

World trade in chemical products may start to decline in 1986

U.S. share of world chemical market is shrinking, as is the long-standing U.S. trade surplus in chemicals

Earl V. Anderson, C&EN New York

The foreign trade balance of the U.S. chemical industry is taking it on the chin again this year. And the outlook for U.S. chemical trade in 1986 doesn't seem encouraging either. In part that's because total world trade in chemicals is likely to ebb next year.

After chalking up a healthy 9% growth last year, overall world trade now is showing signs of slowing down. And when total world trade tapers off, world chemical trade tends to follow.

In the face of such widely fluctuating variables as the U.S. dollar's exchange rate, interest rates, and diverse economic growth in various parts of the world, forecasting world trade is no small task. At the beginning of the year, forecasts tended to converge on a 5 to 5.5% increase in world trade for both 1985 and 1986.

Now that international economists can get a more complete view of 1985 and a closer look at 1986, they agree that those forecasts may be too optimistic. The U.S. economy, which has been the locomotive pulling the rest of the world out of recession, didn't perform up to expectations during the first half of the year. Neither did the economies of many Southeast Asian nations.

Debts continue to stymie many Latin American countries. Meanwhile, less expensive oil is proving to be a burden to most oil-rich countries. They no longer have a wallet full of money to buy manufactured goods from industrialized nations. Saudi Arabia is a prime example.

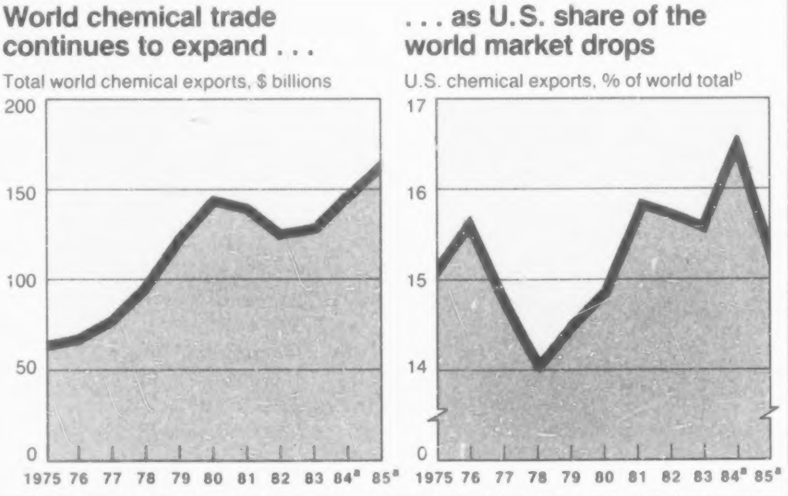
Economists at the General Agreement on Tariffs and Trade (GATT) put it bluntly. Economic recovery throughout the world is slowing more than expected this year. This, they say, "could signal that the world economy is in danger of slipping back into the anemic performance of the post-1973 era."

As a result, GATT economists now think that final figures on world trade for 1985 will show it to have grown only 4% rather than 5.5%. Estimates for 1986 world trade growth are being scaled down, too.

U.S. chemical trade—indeed, all U.S. trade—has not escaped these worldwide trends. The U.S. trade deficit will leap from last year's \$123 billion to about \$150 billion in 1985, based on CIF values for imports that include freight and insurance costs. Using the conventional "customs" basis for valuing imports, the U.S. trade deficit this year probably will be about \$125 billion. The comparable 1984 number was \$108 billion.

Although the U.S. economy has not been so strong as some economists expected it to be, it nevertheless was strong enough to suck in 4% more imports this year (for a total of \$340 billion) than in 1984. Lower crude oil prices cut the U.S. oil import bill 15% to about \$48 billion. Agricultural and commodity imports remained essentially unchanged. The big import gains, then, came in manufactured products.

Although U.S. imports are grow-



World chemical trade continues to expand . . .

. . . as U.S. share of the world market drops

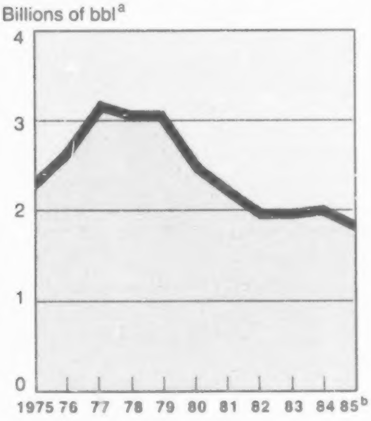
a C&EN estimates. b Defined as: U.S. chemical exports as per cent of world chemical exports less U.S. chemical imports.
Sources: United Nations, Bureau of the Census

In a lackluster year for chemical exports, drugs and fertilizers shine

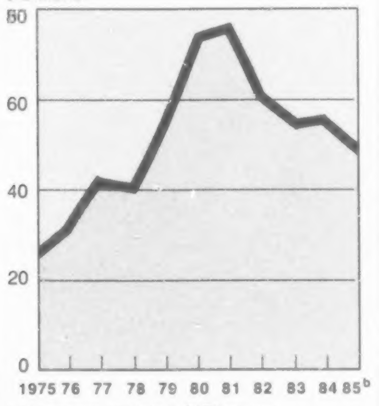
$ Millions	U.S. chemical exports				U.S. chemical imports			
	1985[a]	1984	1983	1982	1985[a]	1984	1983	1982
Organic chemicals	$ 6,050	$ 6,093	$ 5,326	$ 5,440	$ 4,604	$ 4,265	$ 3,477	$2960
Plastics and resins	3,834	4,050	3,732	3,650	1,636	1,484	1,098	766
Medicinals and pharmaceuticals	2,814	2,628	2,494	2,275	1,057	931	703	563
Inorganic chemicals	2,172	2,184	1,838	1,969	1,983	2,064	1,615	1502
Fertilizers, manufactured	2,105	1,815	1,267	1,386	1,013	1,142	997	963
Radioactive materials	1,263	1,421	1,213	1,132	1,346	1,394	952	1143
Pesticides and disinfectants	643	707	630	607	434	308	251	265
Flavors, perfumes, cosmetics, and toiletries	488	498	493	514	550	521	370	295
Pigments, paints, and varnishes	332	335	328	332	246	232	145	103
Cleaning and polishing materials	310	308	295	324	159	118	90	76
Dyeing, tanning, and coloring materials	133	158	163	162	347	358	300	213
Explosives and pyrotechnics	111	146	87	90	116	84	64	67
Miscellaneous	1,905	1,992	1,885	2,010	984	797	717	579
TOTAL	**$22,160**	**$22,336**	**$19,751**	**$19,891**	**$14,475**	**$13,697**	**$10,779**	**$9494**

a C&EN estimates. **Source:** Bureau of the Census

As U.S. imports of oil resume their decline . . .

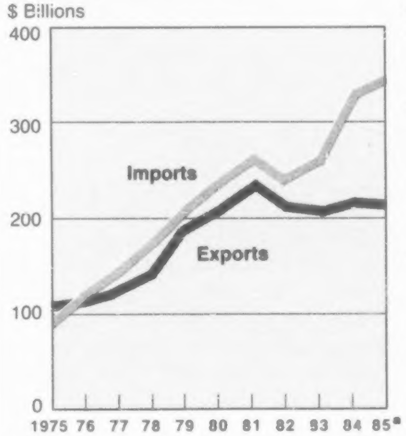


. . . their cost drops substantially

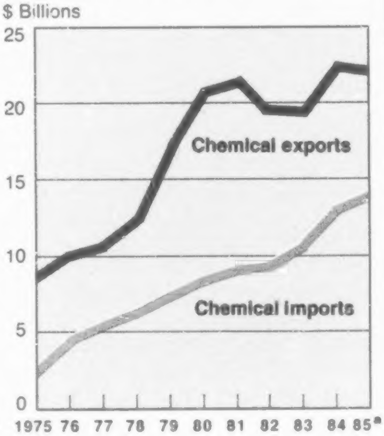


a All petroleum products. b C&EN estimate.
Source: Bureau of the Census

Gap between all U.S. exports and imports widens. . .



. . . while surplus in chemical trade continues to shrink



a C&EN estimates. **Source:** Bureau of the Census

ing, exports this year probably will be down 1.0% or so, to about $215 billion.

U.S. chemical trade fortunes aren't any better. Imports are up, and exports are marginally down. The big difference is that the U.S. chemical trade balance is still in the black. The surplus, however, has been shrinking and it will shrink again this year.

World chemical trade is increasing this year at a faster clip than overall trade. It is likely to be up about 8% to a record $160 billion. This is the strongest annual growth in world chemical trade since 1980.

But U.S. chemical companies didn't capitalize on the opportunity. Last year, U.S. chemical exports jumped 13% to $22.34 billion. This year, they will dip about 1% to $22.16 billion. That performance pushes down the U.S. share of world chemical trade (total world chemical exports less U.S. chemical imports) from last year's 16.5% to 15.3%.

If the steam goes out of the world chemical export market next year, the U.S. chemical industry will have scant hope of pulling its market share back up. Meanwhile, if U.S. chemical companies didn't benefit from this year's strong world chemical export market, who did?

It wasn't the Japanese. Their chemical exports were nearly 3% lower than last year. Canada's chemical exports increased this year, but only about 3% (on a U.S. dollar basis).

Some of the increased chemical trade volume reflects exports from new petrochemical-producing countries, such as Saudi Arabia. Other developing countries, among them Brazil and Mexico, have pushed petrochemical exports, too.

But the big winners are chemical producers in Western Europe. Chemical exports from the European Economic Community, for instance, will probably be 10 to 12% higher than last year's. That's well above the average for overall world chemical exports.

Developing countries largely account for dip in exports

$ Millions	1985[a]	1984
U.S. CHEMICAL EXPORTS		
Canada	$ 2,837	$ 2,752
Latin America	3,701	3,827
Western Europe	6,737	6,497
Eastern Europe	332	275
Japan	2,881	2,961
Australasia	753	842
Communist Asia	554	645
Middle East	399	429
Rest of Asia	3,191	3,292
Africa	443	510
Other	332	306
TOTAL	$22,160	$22,336
U.S. CHEMICAL IMPORTS		
Canada	$ 3,054	$ 3,131
Latin America	1,274	1,208
Western Europe	6,948	6,392
Eastern Europe	304	32[illegible]
Japan	1,419	1,3[illegible]
Australasia	246	251
Communist Asia	159	157
Middle East	203	124
Rest of Asia	434	377
Africa	217	196
Other	217	224
TOTAL	$14,475	$13,697

a C&EN estimates. **Source:** Bureau of the Census

A good share of chemical exports from Western Europe ended up in the U.S. Chemical imports from Western Europe are up 9% this year and have captured 48% of the U.S. chemical import market. Only four years ago, Western Europe's share was 41%.

Indicative of the new kids on the chemical trade block: U.S. chemical imports from the Middle East are likely to increase 64% this year. Admittedly, though, that's from a very small base. Despite the strong gain, those imports will amount to only $246 million this year.

In fact, virtually every chemical-exporting area managed to sell more chemicals to the U.S. in 1985. U.S. chemical companies, meanwhile, found their overseas markets drying up. They improved sales in only two of their major foreign markets—Canada and Western Europe.

The gain in U.S. chemical imports coupled with the slight shrinkage in exports has pulled the chemical industry's cherished trade surplus down below $8 billion for the first time since 1978. And, at an estimated $7.69 billion, it is a worrisome 37% below its record $12.1 billion set in 1980.

In the past five years, U.S. chemical exports have grown only 7%. That's not average annual growth—it's for the entire five years. Chemical imports, meanwhile, have grown 10 times as fast—about 68%.

The reasons, by now, are well documented. The muscular dollar, faster economic growth at home than in other countries, and debt-ridden developing nations are some of the major ones. But there really are only two major trouble spots. Among the industrialized areas, it is Western Europe. Latin America is the Achilles heel among developing areas.

Since 1980, the U.S. chemical trade balance with Western Europe has shifted from a strong surplus to a deficit this year. The five-year swing amounts to $2.7 billion. The U.S. still has a trade surplus with Latin America, but the surplus is $1.9 billion thinner than it was five years ago.

If it were not for those two areas, the U.S. chemical trade situation would not be so bleak. As it stands now, however, U.S. chemical trade has deficits in four of its major product classifications: radioactive materials; dyeing, tanning, and coloring materials; flavors, perfumes, cosmetics, and toiletries; and explosives and pyrotechnics.

Of them, the dyes and flavors categories are by far the most significant. U.S. dyes trade has slipped from a lowly $9 million deficit in 1980 to a $214 million deficit this year. The U.S. now imports 2.6 times the amount of dyes that it exports. In flavors and related products, the U.S. has gone from a $177 million surplus five years ago to a $62 million deficit in 1985. Little wonder that industry leaders are concerned about pending U.S. trade policy and the upcoming multilateral trade talks. □

Declining agricultural exports and rising manufactured imports widen U.S. trade deficit

	U.S. exports				U.S. imports			
$ Billions	1985[a]	1984	1983	1982	1985[a]	1984	1983	1982
Chemicals	$ 22.2	$ 22.3	$ 19.8	$ 19.9	$ 14.8	$ 13.7	$ 10.8	$ 9.5
Machinery and transportation equipment	95.5	90.0	82.6	87.1	134.3	119.2	86.1	73.3
Other manufactured goods	29.9	30.8	30.0	32.7	92.7	88.6	66.5	61.2
Food and live animals	19.3	24.5	24.2	24.0	19.0	18.0	15.4	14.5
Beverages and tobacco	2.6	2.9	2.8	3.0	3.7	3.7	3.4	3.4
Mineral fuels, lubricants, and related materials	9.5	9.3	9.5	12.7	52.2	61.0	56.0	65.4
Crude materials (inedible) other than fuels	17.4	20.2	18.6	19.2	10.9	11.1	9.6	8.6
Animal and vegetable oils and fats	1.5	1.9	1.4	1.5	0.7	0.7	0.5	0.4
All other products	10.9	10.1	7.0	6.9	11.2	9.8	7.7	7.7
TOTAL	$215.0[b]	$217.9[b]	$200.5[b]	$212.2[b]	$339.5	$325.7	$258.0	$244.0

a C&EN estimates. b Includes re-exported imports (not included in individual product categories). **Source:** Bureau of the Census

Growth in chemical output slows a bit, but business generally is healthy

Increasing competition in foreign and domestic markets and continuing excess capacity cloud outlook for chemicals

Dermot A. O'Sullivan, C&EN London

West European chemical companies came through 1985 in a generally good state of health. Demand for a broad spectrum of chemicals held up well, and many plants ran close to capacity.

"There is more optimism in Europe than I have seen in the five years I've been here," remarks Jim Bayne, treasurer of Brussels-based Essochem Europe. "Europeans have adjusted to the energy shocks of 1973 and 1979, and terms of trade seem finally to be working in our favor. This, coupled with a weaker dollar, declining inflation, and reduced budget deficits, may well lead governments to opt for more growth-oriented fiscal and monetary policies."

BASF chairman Hans Albers says, "BASF is in fine shape. We have finished three quarters of 1985 with good results." In much the same vein, Bayer chairman Hermann-Josef Strenger notes that business this year has turned out to be better than expected. And Wolfgang Hilger, who took over as chairman of Hoechst earlier this year, states, "There ought to be no doubt that we shall be able to present a favorable financial statement for 1985."

The optimism is borne out by the financial results of European chemical companies. BASF recorded the biggest gain in pretax profits during this year's first nine months, with a 34% rise above the year-earlier level to about $92.3 million. Akzo increased pretax earnings 22% to $312 million and Bayer 14% to $940 million.

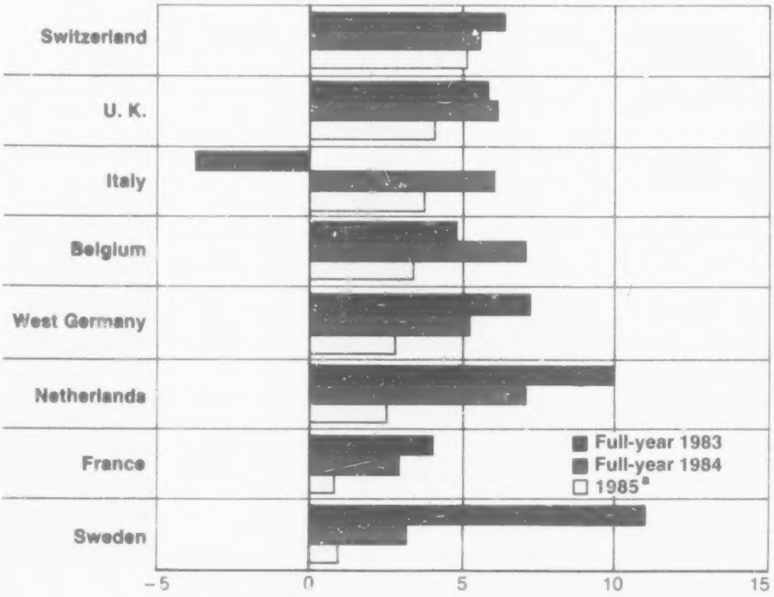
In comparison, Hoechst's 11% advance (to $883 million) appeared modest. The principal factor that depressed its results was the weak showing of American Hoechst, its U.S. subsidiary.

For Imperial Chemical Industries (ICI), on the other hand, earnings fell 8% from the corresponding 1984 period to $1.09 billion. The downtrend has resulted largely from the relative strength of the British pound against the West German mark and the U.S. dollar.

Currently, the pound stands at about 3.7 deutsche marks. U.K. economists argue that the pound is at least 10% overvalued when gauged against differences in economic fundamentals of the two countries, such as rates of inflation and industrial production. Such considerations, the economists say, suggest that the exchange rate of the pound should be nearer 3.3 marks. This is important, because profit margins of U.K. producers are being squeezed on a variety of petrochem-

Output of chemicals is rising more slowly this year

% change from previous year

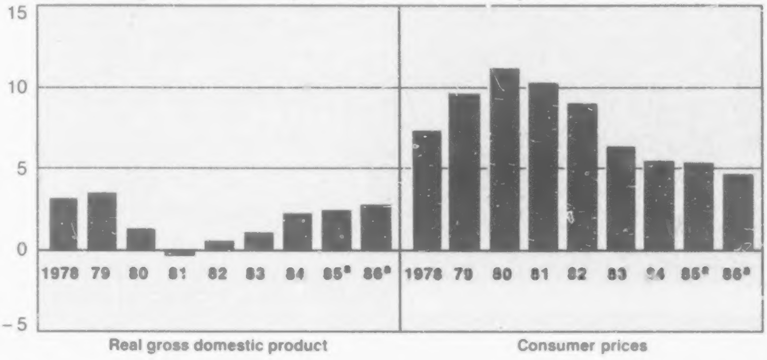


[a] 1985 data are estimates for full year for Belgium and France and for first nine months for other countries.

Sources: National chemical federations for each country

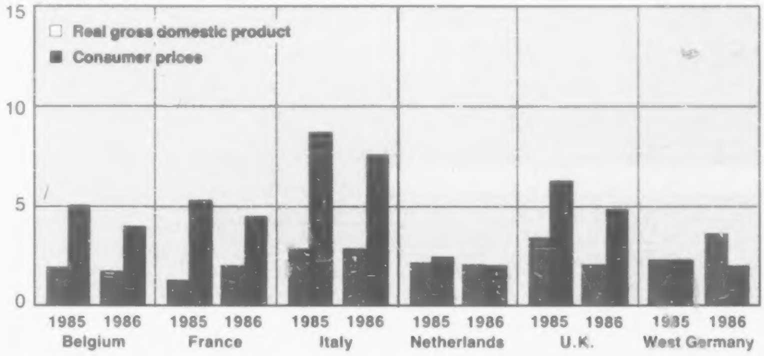
Economic growth is moderate but inflation remains low . . .

% annual change for overall European Economic Community



. . . with West Germany expected to show the best results

Estimated % annual change



a Estimates.
Sources: Commission of the European Communities, Organization for Economic Cooperation & Development

icals that in Europe are quoted in marks.

Meanwhile, the weakening of the dollar, which set in earlier this year, is being viewed with some apprehension by European chemical firms. Ironically, the revaluation of the dollar vis-à-vis the major international currencies has stemmed from demands by finance ministers of a number of countries that the U.S. government take action to stem its rise.

The dollar has gone from strength to strength in the past few years. Compared with its value in January 1982, by March this year it was up almost 74% against the French franc, 44% against the West German mark, and 70% against the Italian lira. In the case of the U.K. pound, when the dollar peaked in February it was 72% higher over the same time span. Similar increases were registered against other European currencies.

Recently, however, the dollar has weakened. Between this year's peak levels and the end of November, the dollar declined more than 24% against both the franc and the mark, 18% against the lira, and 26% against the pound.

Of course, an advantage stemming from a weaker dollar is that oil and naphtha, which are priced in dollars, are cheaper to buy in local currency terms. But that gain is offset by some decided disadvantages.

One of those is that European companies are losing the competitive edge they have enjoyed on exports to dollar trading areas. Consequently, profit margins are being whittled as exporters strive to protect their share of the market. In addition, a weaker dollar results in U.S. chemicals and other goods costing less in West European markets.

"The weakening dollar will put some pressure on the economies of Western Europe as domestic markets must absorb products that were being exported to Third World countries," admits Thomas A. Sparta, executive vice president of Dow Europe, which is heading for a record year. "However, I don't think the economies of those countries have yet peaked, so they will support continued growth for many parts of the chemical industry.

"The dollar's decline so far has not created severe changes in world supply patterns. But the situation must be monitored very carefully. Further decline could shift the competitive positions of major producing nations."

The weakening dollar has an additional effect on European companies with sizable U.S. sales. (In the case of ICI, for instance, the U.S. accounts for about a quarter of its annual sales.) Profits generated by those sales appear smaller when the dollar values are translated into the currency of the countries where those companies are headquartered. The converse also holds, of course. The European activities of U.S. companies are looking healthier than they have in the recent past.

On the broad economic front, government policies throughout Europe appear to have brought inflation further under control. For the European Economic Community as a whole, consumer prices this year are up, on average, 5% from a year ago, the smallest rate of annual increase since 1970.

West Germany and the Netherlands show up best, with consumer prices slightly more than 2% higher than in 1984. Other EEC members, except Greece, where inflation is running at about 20%, have cut the annual increase well below the levels that existed a few years ago. Further improvements are forecast for 1986.

But concern still centers on high unemployment. Ireland, where 17% of the working population is without jobs, is the worst off. Double-digit jobless figures also show up in Belgium, France, Italy, the Netherlands, and the U.K. Throughout EEC, unemployment has climbed to the current average of 11.2% of the labor force.

The 1985 annual economic report of the Commission of the European Communities states, "The apparent inevitability of the prospect of persistently high unemployment has led to widespread pessimism with regard to economic policy. If the relationship between growth and employment observed in the 1960s still applied, medium-term growth rates above 6% would be necessary to achieve the increase in employment (between 1 and 1.5% yearly) needed to bring down unemployment gradually but significantly. Such rates of growth are at present quite unattainable."

This year, EEC's gross domestic product will be up 2.3%, on average, from 1984. The U.K. will register the highest rate of growth (3.4%), France the lowest (1.2%). Next year, an average increase of 2.5% is forecast.

As for growth in chemical output in Western Europe, the trend is down. The biggest dip will occur in the Netherlands and Sweden. For Belgium, the 1985 increase is only half that of 1984.

However, at least one segment of the chemical industry—synthetic fibers—has gained ground this year. All the European producers are making a profit, reflecting sales that are healthier than had been forecast earlier and better utilization of capacity in the wake of major slimming moves in previous years. On average, plants are running at better than 85% of capacity, several percentage points higher than in 1984.

Polyester fiber has outpaced the rest, with this year's output likely to be 1.91 billion lb, 12% more than in 1983. Production of acrylic fiber will be 1.86 billion lb, up 11%; that for polyamides 1.44 billion lb, up 9%.

Western Europe has been the target of sizable quantities of imported acrylic fiber, much of it from plants in Turkey. This year, imports will total about 59 million lb, down from 77 million lb last year. The decline follows antidumping moves taken recently, which should lead to a further reduction in imports. Meanwhile, France's Rhône-Poulenc has dropped out of acrylic fiber production with the closure of its 55 million lb-a-year plant, deemed too small to be operated economically.

The dispute between Akzo of the Netherlands and Du Pont over patent claims involved in production of aromatic polyamide (aramid) fibers continues. Du Pont contends that Akzo's route to the high-strength fiber infringes its patents. The charge has been upheld by the U.S. International Trade Commission, which has issued an exclusion order that will prevent Akzo from exporting its aramid fiber, tradenamed Twaron, or products made of it, to the U.S. unless licensed by Du Pont. Akzo, on the other hand, maintains that the ruling does not apply to goods incorporating Twaron that its customers make.

Nevertheless, both firms are going ahead with plans to make the fiber in Europe. Akzo's fibers subsidiary, Enka, partnered with Northern Development Co., an arm of the Netherlands government, is due to start production shortly in a plant with an annual capacity of 11 million lb. Du Pont has chosen Maydown, in Northern Ireland, as the site for its 15.4 million lb-a-year Kevlar aramid fiber plant, due on stream in 1987.

In another fibers-related move, Du Pont is investing $120 million in a plant in Luxembourg to make Tyvek spun-bonded high-density polyethylene. It will have an initial capacity of 44 million lb annually when completed in 1988. Tyvek nonwovens are used for making a variety of items, such as disposable garments and hospital sheeting, waterproof envelopes, and sterile packaging.

Business for another segment of the European chemical industry—fertilizers—also has been fairly good this year, with two exceptions: urea and phosphate-based compound fertilizers. Urea prices have fallen about 50% since January, influenced by reduced purchases by China and India, and by increased availability—especially from Eastern Europe and from new producers in Indonesia.

"We foresee fierce competition in urea, and rather depressed prices for all other fertilizers exported overseas," contend managers of the business at DSM in the Netherlands. "Urea prices will not recover quickly, but a gradual improvement in 1986 is expected. In Europe itself, there will be some pressure from outside, which might hamper a strengthening of prices."

Fertilizer sales outside Western Europe are priced in dollars. Here again, a lower dollar results in lower profitability for European export sales, and imports into Europe tend to increase. Raw material prices, too, are influenced by the dollar exchange rate.

One of the uncertainties ahead is the increasing problem of obtaining foreign currency exchange permits for fertilizer imports by developing countries. Another is the outlook for farm income, both in Europe and the U.S.

Much will depend on the level of use next spring, and on the prices guaranteed farmers in EEC. Normalization of fertilizer use in China and increased purchases by the Soviet Union would help the situation. However, "These issues are wholly or partly dictated by politics," DSM managers note.

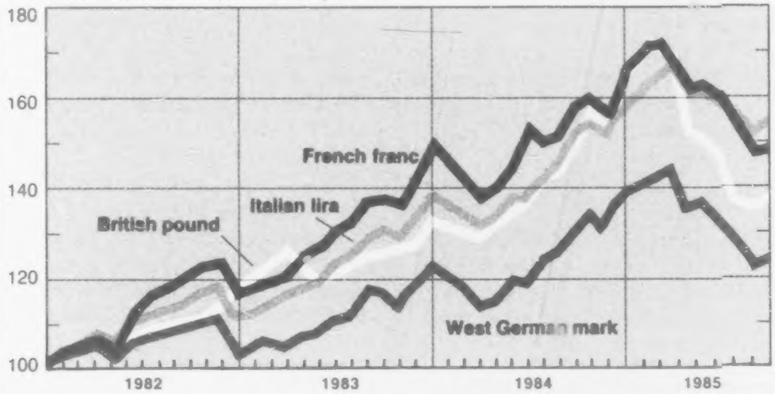
Moves already are under way to improve profitability of the West European companies' operations. For instance, DSM's fertilizer division is putting in a major nitric acid facility in the Netherlands. Due on stream in 1987, it will be capable of making more than 1.47 million lb daily, with resulting economies of scale. Earlier this year, DSM started up a 968 million lb-a-year ammonia plant designed to use 20% less energy than older ones. ICI also is replacing two ammonia units in the U.K. with plants using its own energy-efficient process. Their combined annual capacity of 660 million lb will match that of existing plants being scrapped.

Restructuring moves also have taken place this year within the fertilizer industry. Most notable was Norsk Hydro's acquisition of Ruhrstickstoff, fertilizer arm of Veba, a West German oil and chemicals concern. Norsk also has agreed to take over a major stake in Cofaz, France's second largest fertilizer producer.

Western Europe's petrochemicals producers have experienced a mixed year. Business held up fairly well in the second and third quarters, but was weak in the opening and closing months. The consensus is that 1985's profits won't be so good as 1984's.

The dollar tumbles from last winter's heights

Relative value of U.S. dollar vs. French franc, West German mark, Italian lira, and British pound[a]



[a] January 1983 = 100. **Note:** During January 1982, the average value of the U.S. dollar was 5.825 francs, 2.29 marks, 1227 lira, and 0.53 pound. **Source:** International Monetary Fund

"There has been a slide in prices for certain commodities in the fourth quarter," notes Heinz Klaar, head of lower olefins and derivatives operations at Shell Chemical International Trading Co. "We are on the downside slope of a hill. And 1986 undoubtedly will be more competitive. On the other hand, if demand continues worldwide at the level that it is right now, I could be cautiously optimistic. But 1986 won't match 1984 either."

Ethylene went through an unusual period in Europe around midyear. Long in oversupply because of excess cracker capacity, four units were put out of production as a result of accidents. All told, output equivalent to 3.36 billion lb a year was knocked out of commission. Two of the units, those belonging to DSM in the Netherlands and Statoil of Norway, are back on stream. There's some question as to whether the 441 million lb West German unit of Rheinische Olefinwerke, a joint venture between BASF and Shell, is to restart. However, EniChem expects to restart its 1.32 billion lb plant in Italy before mid-1986.

Because of the shutdowns, ethylene availability became tight almost overnight. Not surprisingly, prices went up and for some weeks ethylene had to be shipped into Europe by tanker for the first time. Since the return of supply to near normality, prices have drifted down again, aided by the cheaper cost of naphtha and gas oil, quoted in dollars, in local currency terms.

A few weeks ago, Europe saw the startup of an ethane-based cracker at Mossmorran, Scotland. Owned and operated by Essochem, Shell Chemicals U.K. funded half the $580 million cost and takes half the 1.1 billion lb-a-year output as feedstock for its petrochemical units at Carrington, near Manchester. Essochem, meanwhile, ships its share to continental Europe. The European branch of Exxon Chemical now will dismantle its 990 million lb cracker at Cologne, West Germany.

Western Europe's ethylene consumption this year will be about 27.5 billion lb, marginally more than last year. Cracker capacity stands at about 31 billion lb. If, as some fear, ethylene derivatives and ethylene itself flood Europe in increasing quantities from plants in Saudi Arabia, more cracker shutdowns will be needed, and that will be when the really tough decisions will have to be made.

Because of the phaseout of napththa and gas oil crackers, European availability of propylene, coproduced with ethylene, is on the decline. But demand is rising, mainly as a result of the building of new polypropylene units. Existing polypropylene plants are running flat out. And most European producers are expanding. Some propylene can be recovered from refinery streams, but at higher cost. As a result, increasing quantities are being imported into Europe, mainly from the U.S.

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Ethylene isn't the only petrochemical in oversupply in Western Europe. Downstream products are, too. Herman Scopes, a director of ICI's petrochemicals and plastics division, notes that overcapacity of polystyrene stands at 23%, that of polyethylenes at 25%, and of polyvinyl chloride at 30%. For ethylene oxide, he pegs the overcapacity level at about 32%.

"A bold restructuring and reduction of capacity for the standard plastics must be at the center of our endeavors," says Manfred Roh, president of the Association of Plastics Manufacturers in Europe. "Only in good business years are these steps thinkable and easy to carry out. The present time encourages voluntary action without state intervention and help.

"Overcapacity should be dismantled on the individual initiative of the firms involved, according to the economic rules of the market. However, to lighten the adjustment process for our industry, we will advocate trade policy measures within the framework of the General Agreement on Tariffs & Trade protection clauses."

David F. Oxley, associate director at Chem Systems International in London, who keeps close tabs on worldwide polymer markets and trade patterns, foresees growth rates for West European consumption of the commodity plastics slowing between 1985 and 1995 from their present level. Even growth in demand for linear low-density polyethylene, now advancing about 33% annually, will slacken to about 11% a year during the next 10 years.

Much to the relief of the West Europeans, the amount of Saudi Arabian petrochemicals entering their domestic markets this year hasn't been so significant as had been feared. Nonetheless, the likelihood of imports from Saudi Arabia creates a certain amount of nervousness throughout the marketplace, even though the volume penetration isn't large.

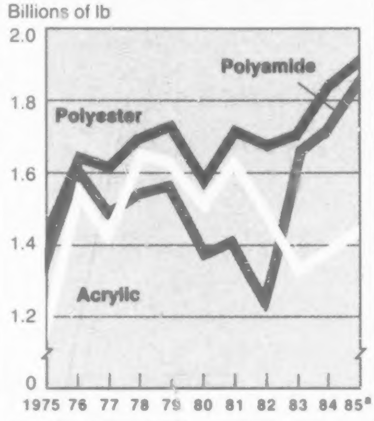
"During most of 1985, when polyethylene was in short supply in Western Europe, imports from Saudi Arabia helped meet customer requirements," observes Karl L. Boehmer, plastics vice president at Essochem Europe. "With the business turning down later in the year, competition from Saudi material has become more noticeable."

The recent significant price erosion for conventional low-density polyethylene can hardly be blamed on imports of relatively small volumes of Saudi linear low-density polyethylene, he adds. "Much of the Saudi polyethylene is moving to local and Far East markets and therefore has mainly an effect on exports by West European producers."

Although there undoubtedly is room for more restructuring along the lines advocated by APME's Manfred Roh, this year has seen some major moves by leading chemical makers throughout Europe. ICI, for instance, has bowed out of European low-density polyethylene production with its decision to sell its remaining facility, at Fos in the south of France, to Shell Chimie. (ICI, the pioneer in the development of low-density polyethylene 50 years ago, still makes the polymer in Argentina, Australia, Canada, India, and South Africa.)

Shell is setting up a new company, Société du Polyéthylène de Fos, to operate the 220 million lb-a-year unit, which has been receiving ethylene feedstock from Shell's neighboring 770 million lb-a-year cracker. Meanwhile, Shell will continue to make low-density polyethylene in a 230 million lb-a-year plant nearby.

European fiber production has been rising recently



a Estimates. **Source:** CIRFS (International Rayon & Synthetic Fibers Committee)

This year, too, ICI handed over its 154 million lb low-density polyethylene operation at Rozenburg, the Netherlands, to France's Atochem in exchange for Atochem's units making ethylene oxide derivatives. The Rozenburg plant has been closed down. (Atochem already has capacity for making 781 million lb of the polymer in France.) The products ICI acquired extend its range of ethylene oxide-based chemicals.

There also is a strong likelihood that Bayer will assign its 50% share in Erdöl Chemie's 660 million lb-a-year low-density polyethylene plant in Cologne, West Germany, to BP Chemicals, its partner in the operation. Bayer's Strenger commented recently that Bayer has no direct use for the plant's output. However, Bayer still intends to keep its half-interest in the Erdöl Chemie 836 million lb-a-year (of ethylene) cracker, which provides Bayer with feedstock for fibers and synthetic rubber.

If the move materializes, BP Chemicals will become West Europe's second largest producer of low-density polyethylene after Italy's EniChem. BP Chemicals' present plants in Belgium and the U.K. have a combined annual capacity of 627 million lb.

EniChem and ICI are studying the possibility of collaborating in the production of vinyl chloride and polyvinyl chloride. The companies say the aim is to make maximum use of their most efficient assets and to pool their technical and commercial expertise, "thereby significantly improving the cost structure of the businesses."

The two companies are major producers of the chemicals. In the case of vinyl chloride, EniChem's capacity amounts to 1.86 billion lb; that of ICI is 1.45 billion lb. Likewise, EniChem has annual polyvinyl chloride capacity of 1.70 billion lb and ICI has 1.25 billion lb. Between them, the British and Italian firms share nearly 20% of Western Europe's market for polyvinyl chloride.

Another move involves BASF's purchase of Monsanto's operations at Seal Sands, England. The plants are designed to make 400 million lb of acrylonitrile, 198 million lb of adiponitrile, and 198 million lb of hexamethylene diamine yearly. The acquisition fits well BASF's needs for intermediates for its fibers and plastics operations. □

Growth is sluggish for thermoplastics in Western Europe

Consumption, millions of lb	1980	1982	1984	1985ᵃ	1990ᵃ	199[illegible]	Estimated annual change 1980-90	1985-95
Linear low-density polyethylene	132	297	671	990	2,200	2,850	32%	11%
Polypropylene	2,805	3,125	4,048	4,290	5,060	5,720	6	3
Acrylonitrile-butadiene-styrene	682	704	847	825	979	1,089	4	3
Polystyrene	3,619	3,476	3,751	3,740	4,224	4,554	2	2
Polyvinyl chloride	8,195	7,700	8,371	8,382	9,152	9,900	1	2
High-density polyethylene	3,135	3,080	3,729	3,916	4,070	4,488	3	1
Low-density polyethylene	8,327	7,832	8,206	8,184	7,040	6,600	−2	−2
TOTAL	**26,895**	**26,214**	**29,623**	**30,327**	**32,725**	**35,211**	**2**	**2**

a Estimates. **Source:** Chem Systems International

Strong this year, chemical business may weaken during next 12 months

Chemical companies are being crimped by strong yen abroad and by slower economic growth in their domestic markets

Earl V. Anderson, C&EN New York

Although not the best of years for Japanese chemical companies, 1985 certainly was much better than expected when the year started.

For many of Japan's top chemical companies, fiscal 1985 will go down as a very good year indeed. When it ends (for most firms that will be March 1986), quite a few will chalk up record or near-record sales and earnings. Profit margins will be well above those of the past few years.

But fiscal 1985 is a paradox for the Japanese chemical industry. The first half was robust. During the second half, however, chemical companies have found it increasingly difficult to maintain sales and even more difficult to keep profits from sagging.

Unfortunate for the industry, the second half is more likely to be the harbinger of things to come in 1986. A number of economic screws are turning in Japan that seem certain to pinch the chemical business next year.

Perhaps most painful is the much stronger yen. At the start of the year, the yen traded at 250 to 260 to the U.S. dollar. As recently as August, it was at 237. And by the first of this month, a dollar was worth only 201 yen.

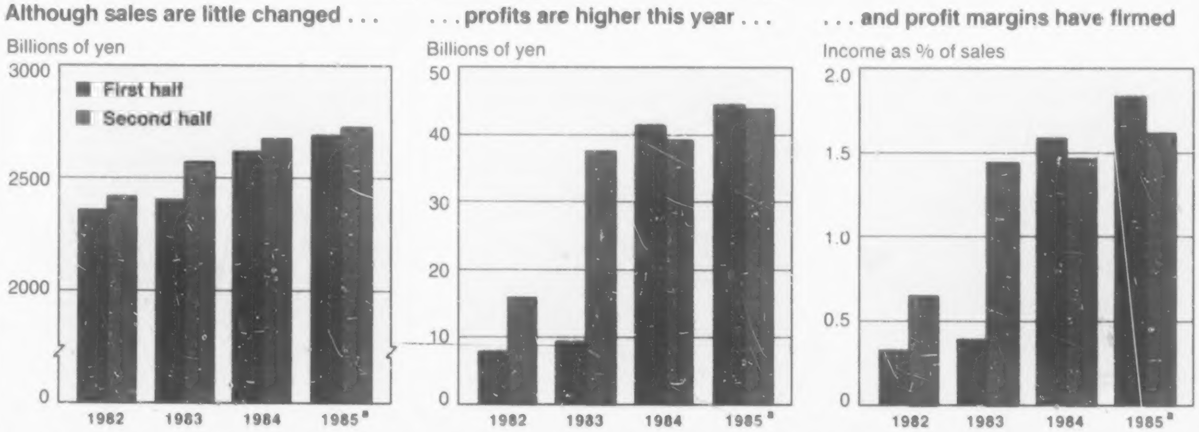
This much stronger yen is putting pressure on Japanese chemical companies in a way that is all too familiar to U.S. chemical companies that have had to cope with a strong dollar during the past few years, a pressure they will continue to feel next year.

Because of the stronger yen, chemical exports have become less competitive in foreign markets, while imports have become more competitive in the Japanese market. Already hurting competitively in international markets, Japanese chemical companies don't need the additional pressure of a stronger yen.

Both chemical exports and imports will be down this year. Exports have been hit particularly by a sharp drop in synthetic resin sales to Southeast Asia, Japan's most important chemical export market. Lower shipments of organic chemicals from the U.S. contributed to the decline in chemical imports.

Total chemical exports will decrease 2.6% to about $7.43 billion, but chemical imports will shrink only 1.2% to $8.25 billion. As a re-

Japanese petrochemical firms gain stronger financial footing



Although sales are little changed . . .

. . . profits are higher this year . . .

. . . and profit margins have firmed

ª Data for second half of 1985 are estimated. **Note:** Data for fiscal years ending March 31. Based on results of 10 leading Japanese petrochemical companies: Mitsubishi Chemical Industries, Sumitomo Chemical, Asahi Chemical Industry, Toray Industries, Mitsui Toatsu Chemicals, Teijin, Showa Denko, Mitsubishi Petrochemical, Dainippon Ink & Chemicals, and Sekisui Chemical. **Source:** Toyo Keizai Shinposha sult, Japan's chemical trade balance, unlike its overall trade situation, will show an $825 million deficit. For the third successive year, Japan has suffered a deficit in its chemical trade.

More ominously, 1985 will be the first year in 20 years that Japan has had a deficit in its petrochemical trade. According to a survey conducted jointly by the Ministry of International Trade & Industry (MITI) and the Japan Petrochemical Industry Association (JPCIA), petrochemical exports through the first nine months of 1985 were 1.2 million metric tons, and petrochemical imports hit 2.0 million metric tons.

By far, the leading imported petrochemical is methanol. Almost 715,000 metric tons were imported during the first nine months, with much of it coming from new plants in Saudi Arabia. Now the Saudis are looking toward Japan as an outlet for even more methanol from their third methanol unit.

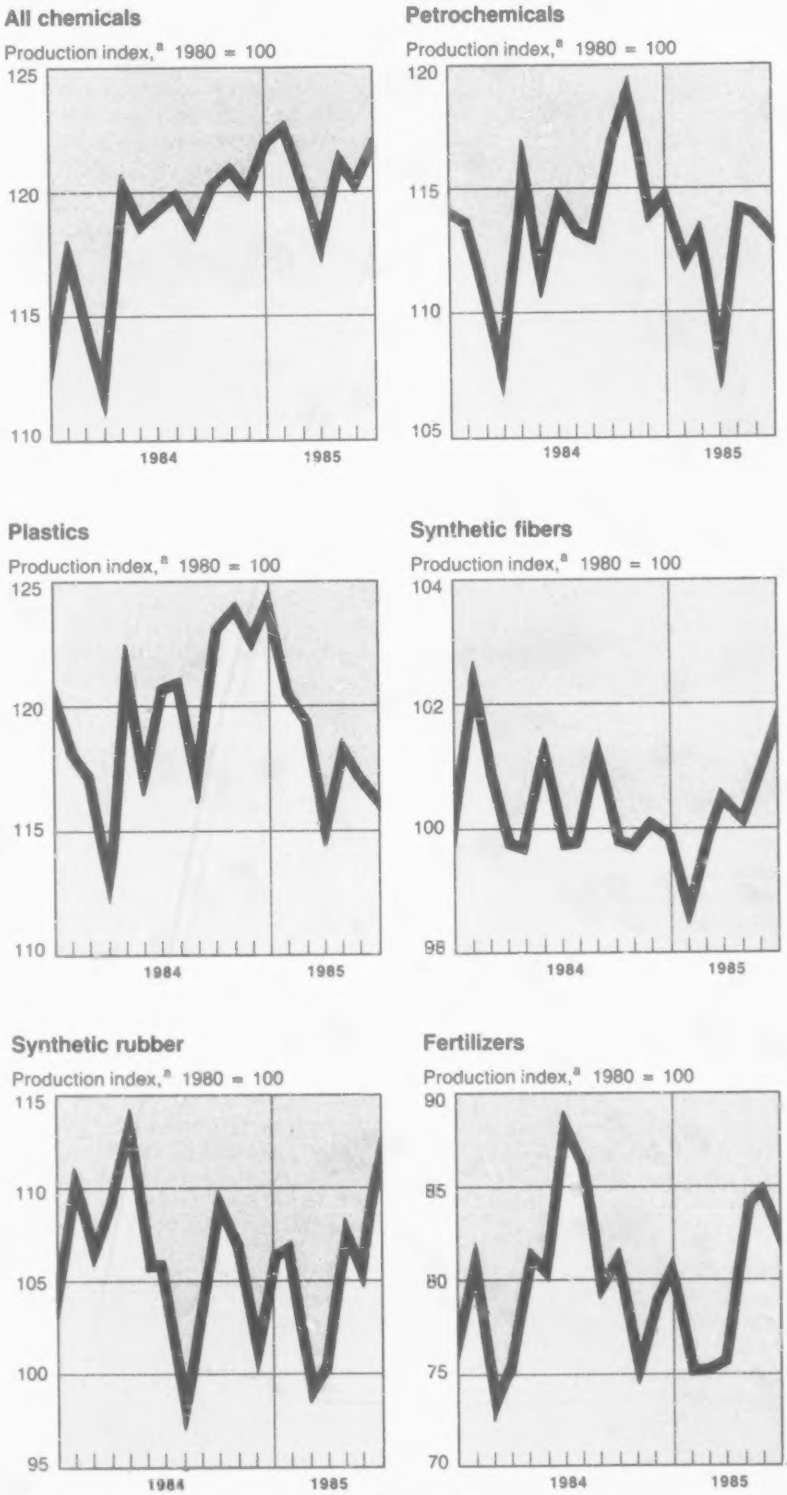
Methanol production in Japan declined steadily between 1979 and 1982 to 625,000 metric tons. Since then, it has plummeted and probably will be no more than 260,000 metric tons this year.

Other major petrochemical imports include ethylene dichloride, styrene, ethylene glycol, acrylonitrile, and polyvinyl chloride. These products, along with methanol, accounted for almost 80% of Japan's petrochemical imports during 1985's first nine months.

Japan's petrochemical import situation is serious. And there's little possibility that it will get better. As a result, MITI has been talking to industry leaders about eliminating the preferential tariffs that Japan gives to petrochemical imports from developing countries.

The obvious target of such a move is Saudi Arabia, which the Japanese feel is so cost-competitive that it doesn't need preferential tariffs. Eliminating preferential tariffs on petrochemicals, however, might not sit well with Japan's trading partners, particularly those developing countries that benefit from them. Japan is, after all, under heavy pressure to make it easier, not more difficult, for foreign products to enter its home market.

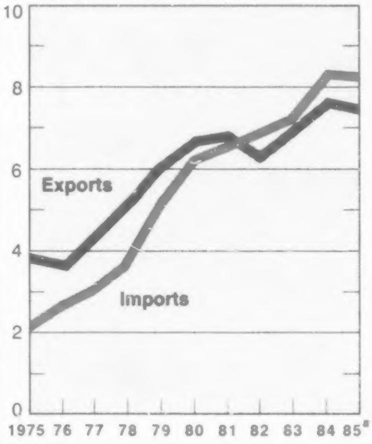
Little growth for chemical output in past two years



a Seasonally adjusted. **Source:** Ministry of International Trade & Industry

Trade deficit widens as both exports and imports dip

Foreign trade in chemicals, $ billions



a C&EN estimates.
Source: Ministry of International Trade & Industry

In one small way, the Japanese petrochemical industry will benefit from a strong yen. Increasingly, basic petrochemical producers have been importing naphtha for feedstock. During the first half of fiscal 1985, petrochemical naphtha imports were up 18% from last year's similar period.

Prices, however, barely nudged upward. A strong yen, then, can mean less expensive imported feedstock for the petrochemical industry. But this lower cost falls far short of offsetting the trade disadvantage of the strong yen.

In fact, some chemical executives believe that cheaper imported naphtha is a bane, not a blessing. Chemical companies have been trying to push through some much-needed price increases, but customers are hanging tough against them. The main reason for their resistance is the stronger yen, which makes imports less expensive. But lower naphtha prices are another reason some customers are seeking lower, not higher, prices on chemicals.

What success Japanese chemical firms have had in ringing up sales and profit gains this year has sprung from their own domestic market. But the Japanese economy isn't expected to be so strong in fiscal 1986 as it has been this year.

Japan's Economic Planning Agency estimates next year's economic growth will be just over 4%, slightly lower than this year's estimated 4.6%. But any decrease in the economic growth, coupled with the yen-actuated trade problems, concerns Japanese chemical leaders.

One reason for the anticipated lower growth rate is a slowdown in private capital spending, which has been a major driving force behind this year's growth. The slowdown already is evident in the chemical industry. Chemical plant and equipment expenditures during the first half of fiscal 1985 were up 33% over last year. During the second half, the increase will be only about 13%.

Little wonder, then, that Japanese chemical companies are furiously pursuing projects they hope will lead to new, higher-value-added products. Biotechnology is a buzzword in Japan, with research spending on it up 50% this year. Other areas that the Japanese consider promising include high-performance resins, composites, specialty chemicals, and ceramics. □

Production is running moderately ahead of last year for most major chemicals

Thousands of metric tons unless otherwise indicated	1984	Seven months 1985	Seven months 1984	% change
INORGANIC CHEMICALS				
Ammonia	2029	1127	1147	−2%
Ammonium chloride	387	225	238	−6
Ammonium sulfate	1829	1082	1059	2
Calcium carbide	478	282	302	−7
Calcium superphosphate	559	329	335	−2
Carbon black	602	368	351	5
Chlorine, liquid	897	552	516	7
Hydrochloric acid	521	319	290	10
Nitrogen[a]	5896	3642	3390	7
Oxygen[a]	7216	4317	4115	5
Sodium carbonate	1036	621	608	2
Sodium hydroxide	3085	1807	1764	2
Sodium silicate	596	335	342	−2
Sulfuric acid	6458	3897	3733	4
Titanium dioxide	205	127	118	8
ORGANIC CHEMICALS				
Acetaldehyde	297	157	164	−4
Acetic acid	350	191	189	1
Acetone	346	134	138	−3
Acrylonitrile	523	311	297	5
Benzene[b]	2013	1172	1140	3
Butadiene	657	364	356	2
Butanol	243	142	137	4
Caprolactam	436	267	250	7
Cyclohexane	492	311	292	7
Dioctyl phthalate	249	141	148	−5
Ethylene	4384	2434	2535	−4
Ethylene dichloride	1939	1105	1123	−2
Ethylene glycol	429	255	234	9
Ethylene oxide	533	323	298	8
Methanol	280	151	171	−12
Octanol	246	126	134	−6
Phenol	272	146	155	−6
Phthalic anhydride[b]	156	95	90	6
Propylene	2981	1685	1683	0
Propylene glycol	205	121	119	2
Styrene	1421	811	786	3
Terephthalic acid	745	466	419	11
Toluene	784	446	442	1
Toluene diisocyanate	76	46	42	10
Urea	1120	614	606	1
Xylene	1401	841	798	5
PLASTICS				
Phenolic resins	334	196	192	2
Polyethylene	2251	1154	1323	−13
Polypropylene	1271	738	711	4
Polystyrene	1503	922	851	8
Polyvinyl chloride	1504	883	874	1
SYNTHETIC RUBBER	1160	679	685	−1

a Millions of cubic meters. b Petroleum-based product only. **Source:** Ministry of International Trade & Industry

Canada

Profits remain elusive for major chemical producers

Slower economic growth may hurt chemical operations, but lower feedstock costs will be a boon for petrochemicals

Earl V. Anderson, C&EN New York

As 1985 draws to a close, Canadian chemical companies are enjoying the third successive year of Canada's strong economic growth. But they might have enjoyed it more.

Despite production gains—in some cases significant gains—and sales increases in some product areas, satisfactory profits have been hard to come by. Too often this year, higher production has resulted from capacity increases rather than strong demand. And customer resistance has kept a lid on price increases.

Whether Canadian chemical companies will be able to improve their profits next year is difficult to predict. Working against higher profits will be an all-too-likely slowdown in Canadian economic growth. Working for them will be new energy policies that could lower feedstock costs for basic petrochemicals producers.

According to the Conference Board of Canada (CBC), the Canadian economy is in for a substantial deceleration. The board pegs growth in real gross national product at 4.5% this year, but sees it sliding to about 2.5% in 1986. What's more, CBC says that growth will continue to slow, with the increase in real GNP growth hovering near 1.5% per year from 1988 to 1990.

Faced with those economic prospects, shoring up profit margins will be no small task for Canadian chemical companies. Much will depend upon how much fat they can trim out of their costs. They already have trimmed a lot, but the new oil and natural gas pricing policies could help. Much, too, will depend upon the fortunes of some of the major chemical-consuming industries in Canada.

It's no secret that some of these industries are in trouble. James D. Hembree, president and chief executive officer of Dow Chemical Canada, points to the pulp and paper industry as one. He quotes Bruce I. Howe, president of B. C. Resources Investment Corp., as saying, "We Canadians are not the world's best hewers of wood any more . . . . Things have changed and they have changed generally for the worse."

The basic problem in pulp and paper, says Hembree, is that the industry isn't generating enough profits to sustain growth. Although its profits did start to make a comeback last year, the industry had only a miserly 2.2% return on sales. Meanwhile, the heavily export-oriented pulp and paper industry faces worldwide overcapacity, which means tough sledding in its foreign markets probably right through next year. The Canadian share of the all-important U.S. newsprint market, for instance, is now less than 60%—far less than its traditional 75% share.

Other market sore spots for Canadian chemical companies are the textile and the metal-mining industries. Canada's textile industry has been hit hard by imports, "perhaps to the point of threatening its survival," says Hembree.

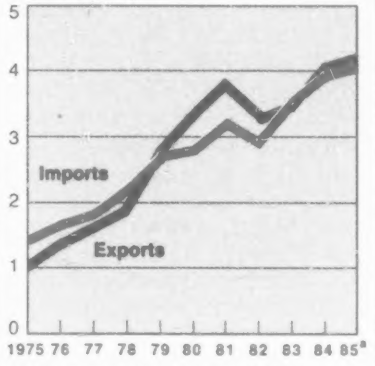
The labor-intensive textile industry has lost a significant number of jobs, first to imports from Japan, now from South Korea and Taiwan. Soon, perhaps, it will lose more to even cheaper imports from China, Thailand, and Indonesia. Hembree says the Canadian textile industry is surviving only because of government support through tariffs and quotas.

The metal-mining industry, meanwhile, has emerged from the reces-

Output surges for ethylene, is little changed for inorganics

Thousands of metric tons	1985[a]	1984	1983	1982	1981	1980
Ammonia	3520	3493	2888	2509	2654	2555
Ammonium nitrate	1040	969	934	1018	1212	873
Ammonium phosphate	1320	1383	1259	888	1355	1466
Benzene	665	557	580	504	571	604
Chlorine	1410	1424	1385	1233	1292	1303
Ethylene	1700	1464	1196	1013	1330	1184
Hydrochloric acid, 100%	160	161	170	135	186	177
Phosphoric acid, 100%	635	691	656	503	744	808
Polyethylene	940	755	623	571	633	641
Polyvinyl chloride	280	252	243	194	222	190
Propylene	630	665	715	618	671	590
Sodium chlorate	330	313	294	264	255	245
Sodium hydroxide	1570	1575	1528	1367	1458	1459
Sulfuric acid	3885	4053	3686	3131	4117	4295
Urea	2000	2110	1445	1231	1303	1274

a C&EN estimates. **Source:** Statistics Canada



Chemical exports hold slightly above imports

Foreign trade in chemicals, $ billions (U.S.)

a C&EN estimates. **Source:** Statistics Canada

sion but is still sick. What recovery there has been is due only to the more "glamorous" metals, such as gold.

As a result of some anemic markets at home and fiercely competitive pricing in their export markets, many Canadian chemical companies are feeling a profit pinch. Du Pont Canada, for instance, had marginally higher sales through the first nine months of the year, but net earnings from operations slumped 62%.

The company notes that, although sales volumes are higher, "intensely competitive conditions in both domestic and export markets [are depressing] prices." That explanation rings true for other Canadian chemical companies, as well.

For the first three quarters, Union Carbide Canada suffered a $4.9 million loss on sales of $348 million. That, of course, doesn't include a $70 million extraordinary charge related to the company's decision to divest its polyethylene plant in Moore Township, Ont. Carbide Canada chairman W. Norman Kissick blames a severe cost-price squeeze in polyethylene for the poor operating results.

Certainly not all Canadian chemical companies are losing money and not all chemical markets are in the doldrums. A significant boost in housing starts has given a lift to construction materials. Industrial fibers and plastics markets also have been strong.

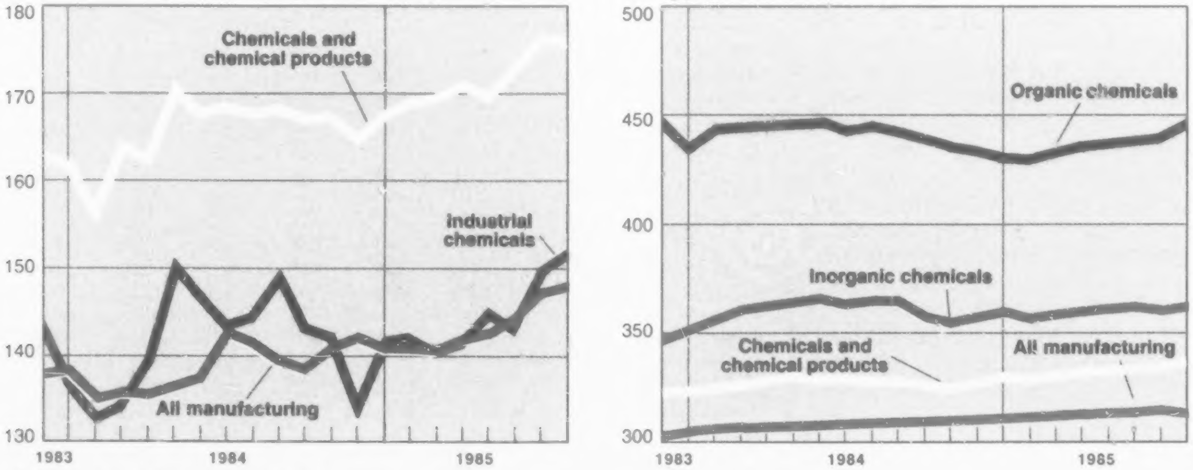
The entire transportation industry, not just cars and trucks, continues to be a lucrative outlet for chemical industry products. And Dow's Hembree pegs the food processing and electrical products industries as promising growth markets for chemicals.

Meanwhile, Canada's new pricing policies for oil and natural gas should help ease the cost-price squeeze by making feedstock prices more competitive. Relief will be felt first by the basic petrochemicals producers, but it should also filter downstream.

The so-called "western accord," signed this spring by the federal government and three western oil-producing provinces, moves previously regulated oil toward "market responsive" pricing. By also removing some costly "up-front" taxes and other charges, it is certain to reduce the cost of oil-based petrochemical feedstocks. How much of a reduction is difficult to say, but petrochemical industry leaders can't help but be pleased with the accord. It follows closely the recommendations made in an industry task force report more than a year ago.

More recently, on Nov. 1, Energy Minister Pat Carney announced a program to deregulate Canadian natural gas markets. The program calls for a one-year transition period. During this time, producers, shippers, and distributors will renegotiate contracts, with the new prices becoming effective next November. If negotiators can't agree by then, prices will be arbitrated.

One thing is certain. Deregulated natural gas prices will be a blessing for chemical plants in the central and eastern provinces. The new natural gas policy will allow consumers to buy gas at negotiated prices. Then, they can either pay transportation costs from, presumably, Alberta to their plant or sell the gas to transporters, and later buy it back. Either way, petrochemical producers should benefit. □



Chemical output edges higher this year . . .

Volume indexes,[a] gross domestic product, 1971 = 100

. . . but chemical prices hold steady

Selling price indexes, 1971 = 100

a Seasonally adjusted. **Source:** Statistics Canada

Saudi Arabia makes its presence felt as a petrochemical producer

With five big chemical plants on stream this year, plans for further petrochemical investment now are being laid

Dermot A. O'Sullivan, C&EN London

When chemical businessmen talk about the competitive threat of chemicals from the Middle East, they are thinking mostly about Saudia Arabia. For that is where the Middle East's largest and most diverse petrochemical operations are centered.

SABIC (Saudi Basic Industries Corp.) is the focal point of Saudi Arabia's petrochemical activities. Since it was set up in 1976, SABIC has completed its plants on schedule and within budget. The achievement is remarkable, considering that a basic infrastructure had to be put in place to service the operations, and that hardware, technology, and skilled labor had to be brought into the country from elsewhere.

This year alone, five major SABIC petrochemical complexes started up:

- Al-Jubail Petrochemical Co., a partnership with Exxon Chemical for making linear low-density polyethylene (572 million lb annual capacity).
- Arabian Petrochemical Co., owned 100% by SABIC, making ethylene (1.1 billion lb).
- Eastern Petrochemical Co., owned jointly with a Japanese consortium led by Mitsubishi, making ethylene glycol (660 million lb) and linear low-density polyethylene (286 million lb).
- Saudi Yanbu Petrochemical Co., a partnership owned jointly with Mobil Chemical, making ethylene (1 billion lb), ethylene glycol (484 million lb), high-density polyethylene (200 million lb), and linear low-density polyethylene (451 million lb).
- Saudi Petrochemical Co., a joint venture with Shell Oil, making caustic soda (829 million lb), ethanol (618 million lb), ethylene (1.44 billion lb), ethylene dichloride (999 million lb), and styrene (649 million lb).

These plants join units that came on stream in 1983 and 1984 and that have a combined annual capacity of 2.75 billion lb of methanol and 1.1 billion lb of urea. But they are not the end. Now nearing completion are units with annual capacities for 660 million lb of vinyl chloride and 440 million lb of polyvinyl chloride. These are owned by National Plastic Co., in which South Korea's Lucky Group has a 15% interest with SABIC. They are scheduled for 1986 startup.

Further off, in 1988, a complex making butadiene, butene-1, and methyl *tert*-butyl ether will be ready. This plant is being built by Saudi European Petrochemical Co., jointly owned by SABIC with Apicorp, an Arab investment corporation, Italy's EniChem, and Finland's Neste. It is designed to produce 275 million lb of butadiene, 176 million lb of butene-1, and 1.1 billion lb of MTBE yearly. Also in 1988, National Chemical Fertilizer Co.'s 1.1 billion lb-a-year ammonia operation is slated for completion.

Additional products that SABIC now is considering include acetic acid, propylene, polypropylene, and synthetic rubber, notes Ibrahim A. Salamah, the company's managing director. And, Salamah points out, "If we need another cracker, we will go for it, although our first priority will be to develop existing crackers."

Discussions that could lead to polystyrene production are in the final stages. Being considered is capacity for 176 million lb of high-impact and general-purpose polystyrene and 44 million lb of expandable material annually. A facility for producing these products could be on stream by early 1988, costing upward to $70 million.

According to Salamah, SABIC'S sales during the first three quarters of this year were $274 million and its net profit was $22 million. SABIC Marketing Services Ltd. now has offices in Hong Kong and London. Arrangements are being made to open a sales office in the U.S., possibly by early next year. "We are late with this," Salamah admits. "We already are selling ethanol and polyethylene in the U.S. We have to be in all the major markets."

Action by the Commission of the European Communities to impose the standard 13.4% import tariff on Saudi chemicals coming into the European Economic Community is a source of friction between Europe and the Saudi government. The duty now applies to methanol and polyethylene and also might go on to ethylene glycol. SABIC management argues that its products should be allowed into EEC duty-free under provision of the General Agreement on Tariffs & Trade, because Saudi Arabia still is classed as a developing country. □

U.S.S.R./Eastern Europe

Soviet Union sets ambitious goals for next 15 years

Chemical industry has a key role in plans to double overall industrial production between now and the year 2000

Richard J. Seltzer, C&EN Washington

The Soviet Union must undertake a "second revolution"—this time of its economy and industry. It must double national income and industrial production by the year 2000. And it must carry out comprehensive "chemicalization of the national economy" by the end of the century.

These ambitious goals—what he calls an "historic transformation"—have been set by the new Soviet leader, Mikhail S. Gorbachev, since taking office last March. Adoption of the goals as official targets—for 1986, for the 12th Five-Year Plan (1986–90), and for the year 2000—will be completed at a Communist Party Congress (held every five years) that will convene on Feb. 25.

When Leonid Brezhnev died in 1982, many observers saw the U.S.S.R. as poised at a major turning point in its history. The country faces serious problems in almost every sphere, with a stagnating economy and industry. Its six East European allies—Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania—face similar problems, and for similar reasons. Thus, industrial output for the six nations rose 2.7% in 1984, after a decline of 2.0% in 1981, zero growth in 1982, and an increase of 2.8% in 1983, according to Central Intelligence Agency calculations. (The goal was 3.7 to 3.8% a year in 1981–85.)

Since assuming power, Gorbachev, 54, has openly acknowledged problems and attacked Soviet economic and industrial failures. The Soviet leader is carrying out a wholesale overhaul of senior positions, installing a younger generation of managers and policy makers. He has launched a tough campaign against alcoholism, absenteeism, and corruption. And he has set out a strategy to meet three competing basic needs: modernizing an aging and often obsolete industrial base; maintaining growth in defense spending; and preserving consumer and social programs.

Soviet Union is East Europe's largest chemical producer

Thousands of metric tons, 1984	U.S.S.R.	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland	Romania
Mineral fertilizers[a]	30,770	695	1191	na	1109	2356	3073
Nitrogen (N)	13,480	486	576	1026	678	1369	na
Phosphate (P_2O_5)	7,660[b]	209	398[b]	na	269	869	na
Potassium (K_2O)	9,630	—	217[c]	3465	162[c]	118[c]	na
Ammonia[d]	17,445	1138	na	na	na	na	na
Sulfuric acid	25,300	908	1240	884	550	2770	na
Sodium hydroxide	2,971	163	325	695	194	379	na
Plastics	4,800[e]	418	1039	1085	383	593	na
Synthetic rubber	1,850	26	71	152	—	119	159

a Nutrient content. b Includes ground phosphate rock for direct application and phosphate animal feed. c Imported potash for producing multinutrient fertilizer. d Nitrogen content. e Includes resins for man-made fibers. na = not available. **Sources:** Central Intelligence Agency, U.S. Department of Agriculture, Foreign Broadcast Information Service, PlanEcon Inc., Council for Mutual Economic Assistance

His strategy is based on increasing the resources available for these needs by accelerating annual growth for the economy and industry to 4.7% a year through the year 2000. This far exceeds growth during the past decade. Total industrial production rose 3.2% a year in 1976–80, by CIA estimates. (Soviet official statistics are higher because of double-counting and disguised inflation, CIA believes.) Industrial output rose only 2.3% in 1981 and 2.4% in 1982, before rebounding to 3.8% in 1983 and 1984, by CIA figures. Through September this year, industrial output rose 3.7% by official figures. (The target set by the Soviet plan for all of 1985 is growth of 3.9%.)

The Soviet Union and East European nations will follow similar paths in their next five-year plans, emphasizing "intensive" rather than "extensive" development. This means increasing output through higher productivity and more efficient management of resources, rather than by raising inputs of fuel, raw materials, capital investment, and labor. It means trying to modernize existing enterprises, instead of constructing new ones. As one Soviet official says, "We have basically exhausted the extensive methods of development."

Raising the quality of goods and services will be stressed. And there is to be a greater role for market forces such as prices, wages and other incentives, and profits. Increased decision making by individual enterprises is to be tried, and the economic bureaucracy will be streamlined. Experiments with varying degrees of autonomy are now under way at some 2300 Soviet enterprises (representing 12% of total industrial output), as well as in several East European countries. (However, Soviet bureaucracies have been assailed for inhibiting these efforts.)

The key to the strategy is more

rapid introduction of scientific and technological advances into the Soviet and East European economies. For instance, all Soviet industrial growth is to stem from higher labor productivity, which is to grow 130 to 150% by the year 2000. This includes "computerization of the economy" and focusing resources on electronics, nuclear power, automation, robotics, and production and processing of new materials. Top priority thus goes to accelerating development of the Soviet chemical, mechanical engineering, and electronic and electrical engineering industries.

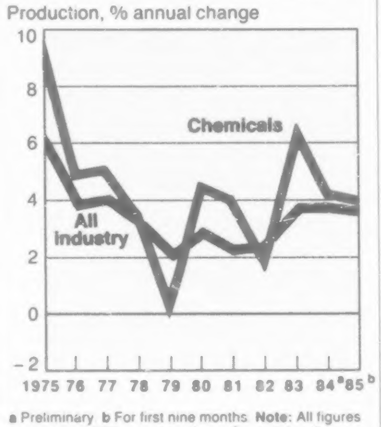
In October, the Soviet Politburo approved a comprehensive program for "chemicalization" of the economy by the year 2000. It provides for substantial increases in output of mineral fertilizers, pesticides, plastics, synthetic fibers, and other chemical materials. Specialty chemicals will receive particular attention. The program also includes major measures to reconstruct and reequip existing plants, introduce automation and mechanization, install more efficient processes, and add production capacity.

Soviet leaders view accelerated growth of the chemical industry as crucial to progress in other key economic areas, including machinery, agriculture, medicine, construction, and transportation. They also view rapid chemical growth as essential to improving the quality, variety, and convenience of consumer goods.

During the next five-year plan, output of the Soviet chemical industry is to rise 30 to 32%. Labor productivity is to grow 29 to 31%, accounting for almost all growth. Production of mineral fertilizers is to reach 41 million to 43 million metric tons in 1990 (up 33 to 40% from 1984). The target for pesticides is 440,000 to 480,000 metric tons on an active ingredient basis (up 29 to 40%), for plastics 6.8 million to 7.1 million metric tons (up 42 to 48%), and for synthetic rubber 2.7 million metric tons (up 46%). Output of reusable polymer packaging is to triple.

In the next five years, the Soviets will step up R&D on and output of modern structural plastics and other polymer materials; low-bulk chemical products, especially organic compounds; vegetable oil and foodstuff substitutes for industrial use; new high-strength, highly elastic, synthetic fibers; radial tires using metal cord, and new large and superlarge tires; and industrial rubber articles.

Chemical growth outpaces that for industry in general



[a] Preliminary. [b] For first nine months. **Note:** All figures except for 1985 are based on Central Intelligence Agency estimates, which are lower than official Soviet statistics because of postulated upward bias in Soviet figures. **Sources:** Central Intelligence Agency, U.S.S.R. Central Statistical Administration

Chemical industry also has high priority in Eastern Europe. In Hungary last year, chemical output rose 4%, up from just 1% in 1983. Growth was led by gases, up 9%, and pharmaceuticals and plastics, both up 7.5%. Chemicals are Hungary's second largest export, and chemical exports paid for in hard currency rose 10%.

This year, the target is 3.3% growth in chemical output, and 9% in hard currency exports. Through August, production was up nearly 4%, the fastest growth of any Hungarian industry. (Industrial output overall rose just 0.4%.) Pharmaceutical production was up 10% in the first half of 1985, double the target. Nearly two thirds of pharmaceutical output is exported, with a goal of $140 million in hard currency exports this year. Hungary has received a $73 million loan from the World Bank to increase production of fine and specialty chemicals oriented toward export, particularly pharmaceuticals.

Romania also targets fast growth for pharmaceuticals, with output slated to rise 69 to 85% by 1990. It planned ambitious growth of 10.2% a year in chemical output for 1981–85. But its output has lagged well behind, especially in fertilizers and synthetic fibers, because it curtailed imports of crude oil to save hard currency. Czechoslovakia, too, is stepping up production of specialty chemicals, planning to make them a quarter of all chemical production by 1995, and to double the percentage exported (now 21.5%).

East Germany's chemical output rose nearly 12% through this September, surpassing most other industries. However, Bulgaria's chemical growth slowed, with production through September of sodium hydroxide, plastics, and phosphate fertilizers well below 1984 levels. Poland will not meet targets, especially because of a horrendous first quarter. Chemical output in January to March dropped almost 5%, with nitrogen fertilizers down 32%.

A degree of skepticism may be in order over the ambitious goals of the Soviet Union and East European countries in their next five-year plans. Despite its high priority and large investments, the Soviet chemical industry often has failed to meet targets. This year, for instance, fertilizer output was to rise more than 10%, but through September it was up just 6%. Production of pesticides and of plastics was up 4% and of sodium hydroxide and sulfuric acid 2%. Chemical output as a whole was up 4%. The industry has been plagued by poor planning, late completion of projects, difficulties in absorbing foreign technology, and inadequate R&D.

Western analysts point out that despite his talk of "revolutionary solutions," Gorbachev is tinkering with the system to make it work better rather than seeking any fundamental structural change. He apparently does not intend to introduce market forces or private enterprise as China —or Hungary to a more limited extent—is doing. Soviet officials stress the necessity of keeping a great degree of central planning and control. But without such structural reform, western observers believe, the Soviet economy will continue to muddle along and not grow to meet its needs and goals. □

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Cover: Possible structure of an aromatic carbon "eggshell" complex of a central metal atom. This particular computer-generated image shows one possible form of a C_{48} carbon shell. Photo courtesy of J. C. Spurlino and F. A. Quiocho, biochemistry department, Rice University

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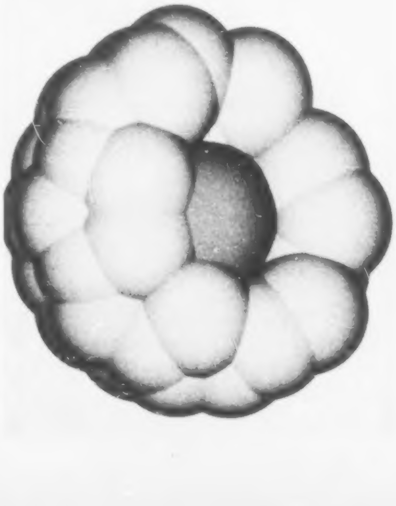


Science

New aromatic molecules from laser vaporization of graphite include stable 60-carbon cluster that is thought to have form of truncated icosahedron. Page 20

Chemical Capital Spending To Gain Little in 1986

Expenditures by major U.S. chemical firms will rise less than 3% next year; outlays this year were up an estimated 6% over 1984

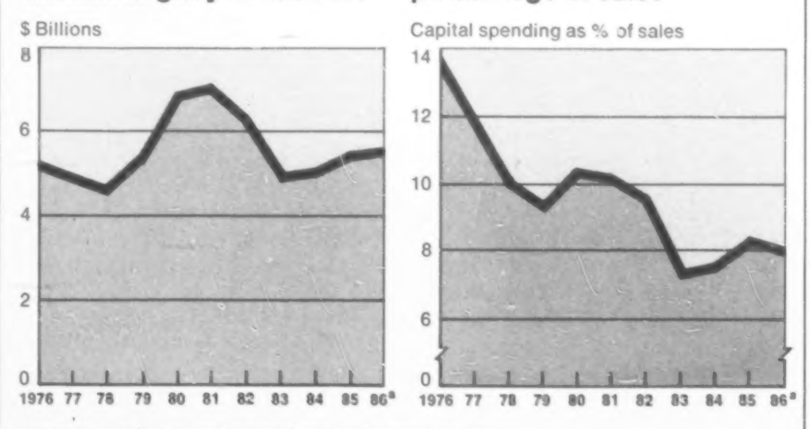
William J. Storck, C&EN New York

Economists across the country are forecasting that general capital spending next year will show little, if any, gain from this year's levels, and that will do little to help economic expansion next year. They point to healthy growth in spending on new plant and equipment in the past two years as one of the reasons that the economy has performed well.

That same lackluster forecast for next year is repeated in the results of a recent C&EN survey of capital spending plans by chemical companies, which shows about the same level of capital expenditures in the industry next year as this year. However, the chemical economy differs from the general economy in at least one major way: Chemical capital spending did not have the post-recessionary spurt that many other industries had in the past couple of years.

C&EN's survey found that 13 chemical producers intend to increase capital spending less than 3% on average next year over 1985 levels. That probably will represent a lowering of real investment, because the rise will be less than inflation, now forecast at about 3.5%. The 2.3% increase for next year follows an estimated 6% rise in 1985 over 1984 capital spending for the same companies.

The chemical industry has had few incentives in recent years for capital spending and, indeed, quite a few disincentives. Chief among these is the capacity utilization rate among chemical makers. In the third quarter, the Federal Reserve Board estimated capacity utilization for chemicals and products at a seasonally adjusted 78.5%, well below the levels needed for additional plant. And for basic chemicals, the capacity use rate is probably even lower. The capacity use rate has been cut by a number of factors including slow demand for many products in the U.S., a heady amount of foreign imports into the U.S., and a low level of exports, which have to compete with cheaper foreign goods in markets outside the U.S.



ª C&EN estimate. **Note:** Combined data from 13 major chemical producers.

In addition, the long-standing relationship between capital spending and interest rates is still continuing, though not as strongly as it was a year ago. In the past few years, chemical prices have been depressed, keeping rates of return from chemical plants below the cost of capital to build new plant. Because interest rates have fallen in the past year, this situation is not as bad as it was, but is still bad enough to put the brakes on capital spending, except for firms that make higher-value-added products.

The slow pace of reinvestment in the chemical industry is causing some concern that many segments of the industry, if they do not begin to build new plants soon, won't be able to compete with imports. Perhaps basic commodity chemicals will become much like the steel industry.

The reasoning works like this: Since it takes two to three years to build a chemical plant, with the current low level of spending, no plants will be completed in the immediate future. If, then, either domestic or export demand increases, U.S. chemical plants may be hard pressed to serve that increase, and foreign imports will have to fill the gap. Further, newer and perhaps more efficient plants being built near lower-cost feedstocks could make imported products cheap enough in the long run compared with U.S.

Capital spending will rise average of 2.3% next year for 13 chemical companies

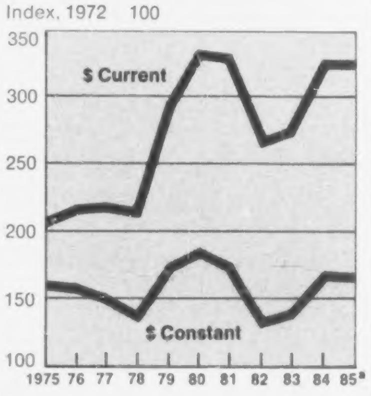
	1986		1985		Worldwide					Change from previous year	
$ Millions	Total	U.S.	Total	U.S.	1985 planned[a]	1984	1983	1982	1981	1986	1985
Air Products	$ 402	$ 317	$ 402	$ 317	$ 325	$ 263	$ 246	$ 347	$ 323	0.0	52.9%
American Cyanamid	200	160	200	160	200	200	165	171	181	0.0	0.0
Celanese	200	185	170	155	200	169	105	275	414	17.6%	0.6
Dow Chemical	900	540	830	498	830	781	630	829	1176	8.4	6.3
Du Pont[b]	1205[c]	na	1180[c]	na	1700	1138	1276	1300	1420	2.1	3.4
Ethyl	135	133	80	78	116	103	85	92	141	68.8	−22.3
W. R. Grace	390	321	450	384	420	380	353	560	657	−13.3	18.4
Hercules	215	161	205	154	210	218	168	174	167	4.9	−6.0
Monsanto	525	473	575	516	575	614	560	673	668	−8.7	−6.4
Olin	110	108	110	108	170	165	123	139	186	0.0	−33.3
PPG Industries	410	349	400	340	400	315	450	452	376	2.5	27.0
Rohm & Haas	200	160	165	132	130	134	72	126	182	21.2	23.1
Union Carbide	670	455	670	455	650	670	761	1179	1186	0.0	0.0
TOTAL	**$5562**	**$3362**	**$5437**	**$3297**	**$5926**	**$5150**	**$4994**	**$6317**	**$7077**		
ANNUAL CHANGE[d]	**2.3%**	**2.0%**	**5.6%**	**3.3%**	**13.6%**	**3.1%**	**−20.9%**	**−10.8%**	**2.4%**		

a Earliest estimates. b Excludes Conoco. c C&EN estimates. d Cumulative change for companies reporting. na = not available.

chemicals produced in aging plants that the imports ultimately may hold sway.

The 5.6% rise in capital spending in 1985 reflects the realities of the marketplace. Earlier this year chemical companies were predicting that capital spending in 1985 would be almost 14% above what it was in 1984. The chemical economy, however, obviously caused moderation. The meager 2.3% rise for next year seems to indicate that chemical company executives continue to believe that demand over the next few years will warrant very little new plant building.

Capital appropriations remained level in 1985



a C&EN estimate. **Source:** Conference Board

Among the 13 companies surveyed, the largest hike in 1985 spending was by Air Products, whose capital spending increased nearly 53% from 1984 to $402 million. That was followed by a 27% increase by PPG Industries to $400 million and a 23% rise by Rohm & Haas to $165 million. The next highest increase was by W. R. Grace, whose capital spending in 1985 is expected to total $450 million, up 18% from 1984. Other increases this year include 6.3% by Dow Chemical to $830 million, 3.4% by Du Pont (excluding its Conoco operations) to $1.2 billion, and 0.6% by Celanese to $170 million.

Two companies—Union Carbide and American Cyanamid—have managed to hold their own this year with no change, with spending of $670 million by Carbide and $200 million by Cyanamid.

Four companies in the survey decreased capital spending in 1985. For Hercules, spending is down 6% to $205 million; Monsanto, 6.4% to $575 million; Ethyl, 22% to $80 million; and Olin, 33% to $110 million.

For 1986, the few companies that are predicting large increases say that the gains are mainly for projects that were deferred from this year. For instance, Ethyl says that its spending, although down 22% in 1985, will increase 69% in 1986 to $135 million. Celanese is projecting an 18% rise to $200 million, following its 0.6% increase this year. Only Rohm & Haas is following a good year with another good year, forecasting that capital spending will rise 21% in 1986, after its 23% rise in 1985.

Dow is projecting that its capital expenditures next year will rise 8.4% to $900 million. Hercules' spending will be up 5% to $215 million, and PPG Industries' will increase 2.5% to $410 million. Du Pont, excluding Conoco, plans to boost its capital spending an estimated 2.1% to $1.21 billion.

Four companies—Air Products, American Cyanamid, Olin, and Carbide—will hold capital spending to 1985's levels. And only two are projecting declines next year: Monsanto says spending will be down 9% to $525 million, and W. R. Grace says its will be down 13% to $390 million.

However, no matter what the forecast is at this time, it is sure to change as market conditions and chemical executives' perceptions of the economy change. A year ago, combined 1985 capital spending by the 13 companies was forecast to be up nearly 17% to almost $6.1 billion. Instead, capital spending this year came in only 5.6% higher at $5.43 billion, more than 10% below the original projection. □

Most biotechnology firms score gains in third quarter

David Webber, C&EN New York

During the third quarter, the best-known biotechnology-based companies moved more products to market, expanded and, in some cases, improved their relationships with larger corporations, and continued to wrestle products through the regulatory process. For many firms, revenues swelled hugely, either because of greater product sales or large, initial collaborative R&D payments. And at others, mounting costs of clinical trials, though a reflection of progress in bringing therapeutic products closer to commercialization, resulted in further losses.

One of the most solid performers in the third quarter was Monoclonal Antibodies, Mountain View, Calif., which reported the first quarterly net income in its history. Its small profit of $122,265 was achieved through a 134% increase in revenues compared with the same period in 1984. Most of that jump came in the marketplace, where the company boosted sales of its antibody-based diagnostic kits 119% from third-quarter 1984. Sales were also up 42% compared with second-quarter 1985 and amounted to 74% of all revenues. Further elevating figures was a one-time payment of $400,000 due to the restructuring of a relationship with Ralston Purina that helped nearly triple contract revenues for the quarter.

In addition, the quarter results probably included the last major expenses related to the company's successful defense of a patent infringement lawsuit brought against it by Hybritech. Monoclonal Antibodies won the suit in August, but still had $355,000 in legal costs in the quarter. Despite a notice of appeal by Hybritech, Monoclonal Antibodies believes the burden of the suit is now essentially behind it.

Laster: close to break-even point

Amgen, Thousand Oaks, Calif., also reported a big jump in revenues—in this case 195%, compared with third-quarter 1984—but the improvement was due entirely to massive initial payments by Johnson & Johnson as part of a joint venture arrangement in erythropoietin, hepatitis B vaccine, and interleukin-2. The payments raised Amgen's R&D revenues, which account for 91% of all revenues, 368%, making it possible for the company to report net income for the quarter of $2.3 million, compared to a third-quarter 1984 loss of $2.0 million.

For BioTechnica International, Cambridge, Mass., revenues surged 332% in the third quarter, thanks to a larger component of contract fees in the revenue mix based on the expansion of several existing contracts and the initiation of some new ones. The climb in revenues brought the company's third-quarter loss down 26%. Over the first nine months of 1985, BioTechnica lost $2.2 million, 30% less than in the equivalent 1984 period.

"These financial results clearly underscore the positive trend toward a breakeven position on an annualized basis as of the final quarter of 1985," says John C. Hunt, chief executive officer. "Beginning in 1986, we will take the next strategic step in BioTechnica's development plan, which will consist of the expansion of the company's product base. Product sales should decrease our dependence on contract research as a percentage of total revenues in the coming year and contribute to our goal of achieving profitable operations in 1986."

Continuing to perform like the Cadillac to which it is often likened, Genentech, South San Francisco, Calif., went through the third quarter in stately fashion, raising net income 47% to $1.6 million on a 16% increase in revenues. As in previous quarters, about 90% of those revenues came from contract fees, but Genentech now has a product on the market in Protropin, its human growth hormone that was approved by the Food & Drug Administration in October. The firm already is receiving royalties on sales of Protropin in Europe from Kabi Vitrum, the Swedish firm that owns manufacturing and marketing rights for the product outside the U.S.

At Biogen, Cambridge, Mass., revenues shrank 30%, owing to a 31% decline in R&D fees and a 28% drop in interest income. At the same time, although overall expenses were less than in the same quarter a year earlier, some costs rose because of continued Phase III clinical trials of Biogen's gamma interferon for use against kidney cancer and other tests of the substance in treating rheumatoid arthritis. As a result, the company's third-quarter loss ballooned to $4.8 million, compared with $2.8 million in third-quarter 1984. Over the first nine months of the year, Biogen lost $12.6 million compared with $10.9 million during the comparable 1984 period.

Centocor, Malvern, Pa., the leading monoclonal antibody-based company now that Hybritech has been acquired by Eli Lilly, added to its record of strong quarterly growth. Third-quarter revenues jumped 60% to $5.6 million, swelling earnings 299% to just under $1 million. For the nine-month period, Centocor's earnings were up 515% on a revenue increase of 76%.

Centocor has been one of the chief beneficiaries of the acquisition of Hybritech and that of Genetic Systems by Bristol-Myers. Stock market investors reacted to the high prices paid for those two producers of diagnostics based on hybridoma technology by buying into Centocor. As a result, the price of Centocor common stock has shot up 49% since

Revenues surged at some biotechnology companies

	THIRD-QUARTER 1985[a]						NINE MONTHS 1985[a]					
	Revenues[b]	Earnings[c]	Change from 1984		Profit margin[d]		Revenues[b]	Earnings[c]	Change from 1984		Profit margin[d]	
	($ millions)		Revenues	Earnings	1985	1984	($ millions)		Revenues	Earnings	1985	1984
Amgen	$ 7.523	$ 2.293	195%	def	30.5%	def	$14.210	$ −1.460	129%	def	def	def
Biogen	5.701	−4.829	−30	def	def	def	17.251	−12.589	−22	def	def	def
Bio-Response	0.923	−0.727	254	def	def	def	2.600	−2.347	267	def	def	def
BioTechnica International	1.340	−0.790	332	def	def	def	3.591	−2.224	261	def	def	def
Bio-Technology General	0.431	−0.641	121	def	def	def	1.191	−2.097	45	def	def	def
California Biotechnology	2.471	−0.157	21	def	def	def	6.833	−0.218	12	def	def	0.0%
Centocor	5.605	0.942	60	299%	13.8	6.7%	15.425	2.241	76	515%	12.0%	3.4
Cetus	9.051	0.108	−56	−71	1.2	1.6	32.449	0.853	−30	0	2.6	1.8
Damon Biotech	0.970	−2.755	−6	def	def	def	2.569	−8.364	−35	def	def	def
DNA Plant Technology	1.182	−0.157	24	def	def	def	3.196	−0.407	33	def	def	def
Genentech	22.153	1.609	16	47	7.3	5.8	63.729	3.425	23	62	5.4	4.1
Genex	4.600	−2.200	−62	def	def	30.8	14.195	−6.800	−44	def	def	def
Immunex	1.041	−0.866	44	def	def	def	2.351	−3.330	15	def	def	def
Molecular Genetics	1.851	−0.559	−19	def	def	2.3	6.092	−1.772	−14	def	def	0.1
Monoclonal Antibodies	2.600	0.122	134	def	4.7	def	5.917	−0.872	111	def	def	def

a For three-month or nine-month period ending closest to Sept. 30. b Includes sales, contract research, royalty, and interest revenues. c Excludes extraordinary credits. d After-tax income as a percentage of sales. def = deficit.

the beginning of September. Seeking to capitalize on that, Centocor last week announced a public offering of 1 million new shares of common stock, a rare event among biotechnology-based companies over the past two years.

At DNA Plant Technology, Cinnaminson, N.J., third-quarter revenues rose 24% compared to the same period a year earlier, and the quarter's net loss shrank to $157,000 from $180,000 in third-quarter 1984. Over the first nine months of the year, revenues were up 33%. Nine-month losses declined 39% to $407,000.

"Our annual rate of revenue from research and product development activities is now above $4 million and exceeds the previously projected level," comments Richard Laster, president and chief executive officer. "While amply supporting our research and product development activities, we continue to be able to operate the company close to breakeven."

Damon Biotech, a contract cell culture company in Needham Heights, Mass., derived all of its third-quarter noninterest revenues from sales of monoclonal antibodies. Sales of these antibodies climbed 220% to $628,000. But because of far lower interest income, total revenues in the company's fiscal fourth quarter, which ended Aug. 31, shrank 6% to $970,274. At the same time, costs and expenses jumped 29%, resulting in a net loss before an extraordinary tax gain of $2.8 million, which is 49% higher than in the same period in 1984.

Third-quarter declines also were reported by Molecular Genetics, Minnetonka, Minn., whose 19% drop in revenues combined with an 8% jump in expenses led to a loss of $558,850, compared to a tiny third-quarter 1984 profit. The company is still struggling to boost sales of its animal health products, which over the first nine months of the year have brought in only 8% more than in the equivalent 1984 period. Molecular Genetics has made changes in its marketing tactics that it hopes will improve sales.

For Genex, Rockville, Md.—now in the midst of a drastic retrenchment—the third quarter marked the final revenues from sales of L-phenylalanine (an aspartame ingredient) to G. D. Searle (now a unit of Monsanto). Searle told Genex last spring that it would stop buying the product after Oct. 1. Because of the end of that vital sales contract, Genex has been forced to shut down the Paducah, Ky., plant into which the company had poured much of its assets. The Paducah employees lost their jobs at the end of October, and some 40% of the staff in the company's headquarters facilities were laid off this month.

In the third quarter, Genex's revenues from product sales dropped—as a result of both the tapering off of Searle's purchases and lower prices—to $4.0 million from $10.7 million in the same quarter a year earlier. Overall, revenues were down 62% in the quarter. As a result, the firm lost $2.2 million in the third quarter, after earning $3.7 million in the equivalent 1984 period. Over nine months, Genex revenues plunged 44% to $14.2 million. The 1985 nine-month net loss was $6.9 million, compared to a marginal profit for the same span in 1984.

Genex now has decided to continue as a contract R&D operation, with the exception of a small effort to market enzyme-based cleaning products. As a result of this return to a smaller scale, three members of senior management resigned at the end of November. In an attempt to recoup its losses, the firm sued Searle in October, alleging that Searle induced Genex by fraudulent misrepresentation to rush L-phenylalanine into production (C&EN, Oct. 21, page 14). The suit, filed in federal district court in Baltimore, seeks at least $40 million in compensatory damages plus punitive damages as well as treble damages under antitrust and antiracketeering laws. ☐

Plastics consumption to top 47 billion lb in 1985

Sales and captive use of plastics in the U.S. will hit a record 47.4 billion lb this year, up nearly 5% from 1984, according to Charles E. O'Connell, president of the Society of the Plastics Industry (C&EN, Dec. 16, page 8). But growth in 1986 will slow to 2%, he adds, because of declining auto sales and housing starts, plus rising imports, which now comprise 4% of U.S. plastics consumption.

Of 1985 consumption, O'Connell estimates that almost 13 billion lb (27%) will go into packaging, nearly 12 billion lb (25%) for building and construction, 4 billion lb (9%) for consumer and institutional products, 3 billion lb (6%) for electrical and electronic parts, 2.4 billion lb (5%) for transportation uses, 2 billion lb (4%) for furniture and furnishings, 2 billion lb (4%) for inks and coatings, 5 billion lb (10%) for other uses, and 5 billion lb (10%) for exports.

The SPI president cautions that such end uses are difficult to estimate this year. This is because of uncertainty in economic performances of individual markets, competition among plastics for many end uses, and a growing amount of "other uses" that includes sales to distributors and compounders who do not report end uses to SPI. In particular, he says, polypropylene and polystyrene are moving into applications previously served by engineering resins.

Among major resins, O'Connell predicts that use of low-density polyethylene will be up 6.9% this year over 1984 to 9 billion lb, high-density polyethylene up 9.2% to 6.5 billion lb, polypropylene up 8% to 5.2 billion lb, and polystyrene up 4.3% to 4 billion lb. His estimates for these and other resins are based on reporting through September of SPI member firms to the accounting firm of Ernst & Whinney.

Polyvinyl chloride use, however, will decrease 1.1% to 6.7 billion lb. This is still a turnaround for PVC, demand for which was falling at the rate of 6% per year in June. O'Connell attributes the ailing PVC market to growing imports of resin and finished goods.

U.S. plastics sales and captive use will be up nearly 5%

Millions of lb	1985 production[a]	% change 1984–85	1985 sales and captive use[a]	% change 1984–85
THERMOSETTING RESINS	**5,665**	**2.1%**	**5,650**	**2.8%**
Phenolic	2,630	5.1	2,640	5.2
Urea	1,240	3.4	1,235	3.9
Polyester, unsaturated	1,230	−0.2	1.230	−0.1
Epoxy	385	−5.2	365	−3.7
Melamine	180	−14.3	180	−8.6
THERMOPLASTIC RESINS	**35,000**	**2.7**	**35,860**	**4.7**
Low-density polyethylene	8,750	4.0	9,000	6.9
Polyvinyl chloride	6,750	−0.1	6,725	−1.1
High-density polyethylene	6,550	7.6	6,500	9.2
Polypropylene	5,075	2.7	5,200	8.0
Polystyrene	3,975	3.6	4,000	4.3
Acrylonitrile-butadiene-styrene	1,000	−11.3	1,000	−8.9
Styrene-acrylonitrile	90	−9.1	85	−3.4
Other styrene-based polymers	270	6.3	270	15.9
Styrene-butadiene latex & other styrene-based latexes	710	−4.7	750	0.1
Thermoplastic polyester	950	5.7	925	7.7
Vinyl acetate	675	−2.2	675	−2.2
Polyvinyl alcohol	145	5.1	140	0.7
Other vinyls	185	−1.1	190	1.6
Nylon	375	−5.3	400	2.8
ENGINEERING RESINS	**925**	**5.4**	**925**	**3.7**
OTHERS[b]	**5,600**	**5.0**	**4,950**	**8.2**
TOTAL	**47,190**	**2.9%**	**47,385**	**4.8%**

a Estimates based on data reported through September. b Including polyurethane.
Source: Society of the Plastics Industry

As for engineering resins, they suffer not only from competition from polypropylene and polystyrene but from slowed growth in their largest outlet, electrical and electronic parts. In addition, O'Connell says, the electrical and electronic industries may be shifting to foreign sources of such parts. Still, engineering resins use will be up 3.7% this year to almost 1 billion lb.

The fastest-growing outlet for plastics is building and construction, he says. Growth this year was spearheaded by pipe and conduit, plumbing fixtures, siding, windows and doors, and thermal insulation. Building and construction is also the market in which plastics have the greatest opportunities to continue to replace other materials.

O'Connell ascribes the healthy growth of plastics packaging itself to consumers' increased acceptance of plastics for self-service merchandising, convenience, and safety. He notes that use of thermoplastic polyester, which is the prime material in the rapidly growing beverage container market, has slowed in growth but still will post a 7.7% increase in 1985 to almost 1 billion lb. In addition to thermoplastic polyester, HDPE also accounts for exceptional growth in rigid containers.

The 5 billion lb of resins exports this year amounts to a 12% rise over 1984. Polyolefins are almost entirely responsible for this rise as their exports increased 700 million lb this year. But O'Connell warns that imports are on the rise as well. Although total imports average only 4% of U.S. plastics consumption, the share is already 10% for styrene-acrylonitrile resins, nylons, and polyvinyl alcohol. The warning signs also are out for LDPE, PVC, and acrylonitrile-butadiene-styrene resins, he says, for which imports are 6% of consumption. Continued increases in imports are likely, because of a U.S. political climate that favors free trade. He cites such Western Hemisphere countries as Canada, Mexico, and Brazil as chief sources of plastics imports. □

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U.S. chemical industry is taking steps to avoid Bhopal-type accidents
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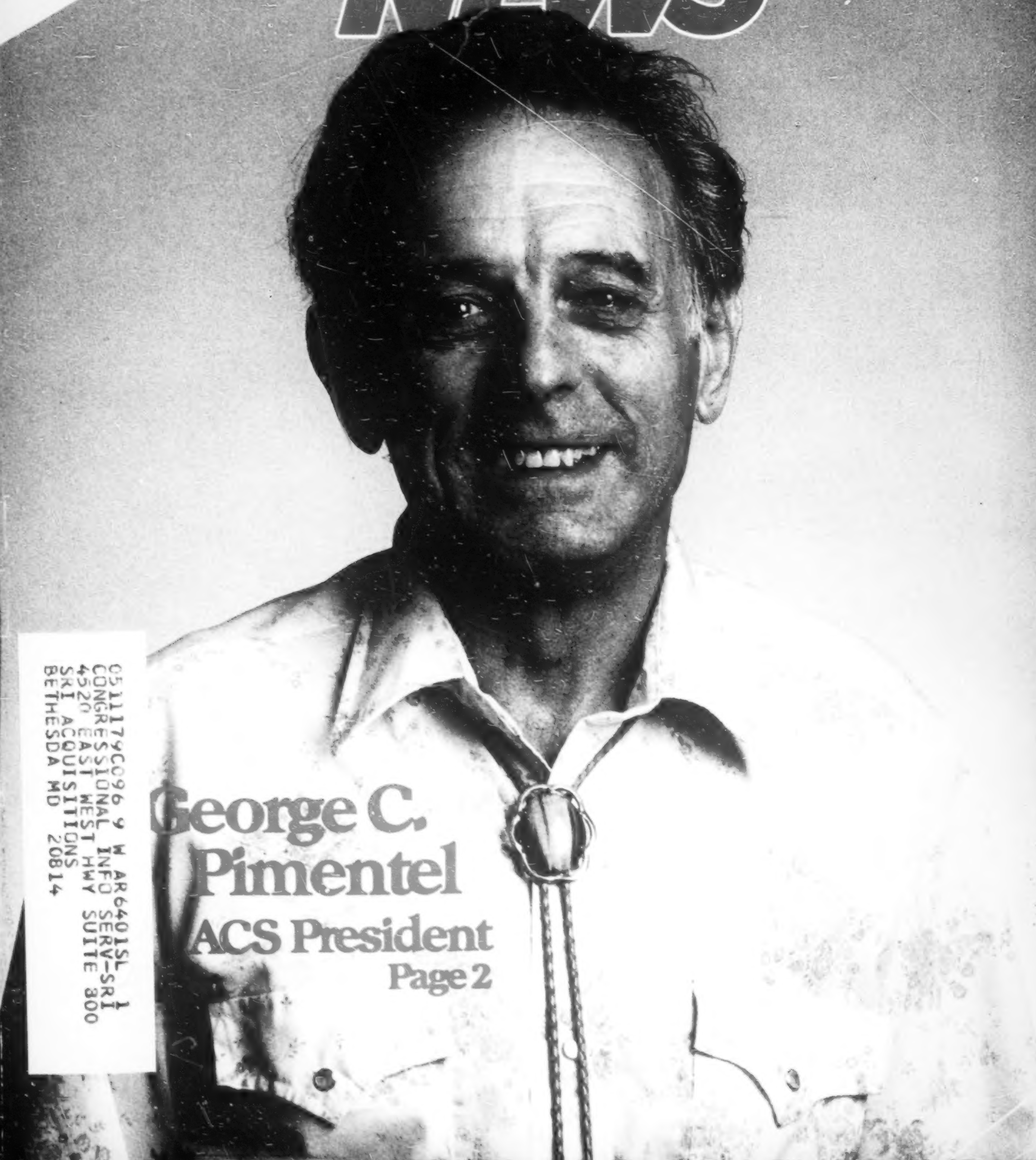

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Cover: Photo by Greg Pease

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Great Lakes Cleanup More Complex than Anticipated

Cutting industrial discharges has had little effect on pollution; emissions into air and groundwater play big role and their control is difficult

The complexities of ecosystems and pollution pathways are hamstringing environmental scientists trying to cleanse the Great Lakes of toxic chemicals.

Considerable progress has been made in recent years in throttling the flow of industrial wastes into these interlocking inland lakes. But scientists are surprised and disappointed at how little this has improved the pollution picture: Residents of the Great Lakes region, they say, still are exposed to "appreciably more" toxic chemicals through contaminated drinking water and food products than other North Americans. This assessment came to light last month after a joint committee of the U.S. National Research Council and the Royal Society of Canada completed a broad review of the Great Lakes Water Quality Agreement between the two nations (C&EN, Dec. 16, 1985, page 13).

The committee noted that "major progress" has been achieved in reducing levels of phosphates and several other pollutants in the Great Lakes. But it also said that further reductions in pollutant levels are urgently needed to reduce the health risks of people using the resources of the basin.

Scientists now realize that "simply going after industrial discharges is not enough," says environmental researcher Orie L. Loucks of Butler University. "The picture is more complex."

Lake Ontario is most polluted of Great Lakes

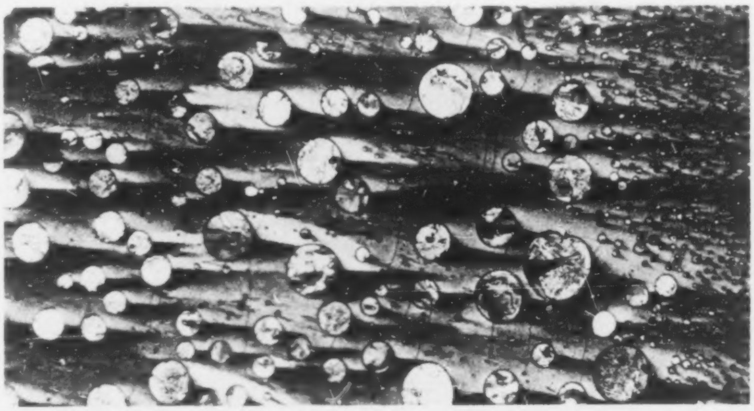
Great Lakes drainage basin limit
Lake Superior
Ontario
Green Bay
Georgian Bay
Lake Huron
St. Lawrence River
Lake Michigan
Lake Ontario
Lake Erie
N
Km
0 100 200
Great Lakes drainage basin limit

Indeed, the pollution of the Great Lakes ecosystem is fed by several different sources. Two of these—groundwater and atmospheric deposition—have turned out to be more important than originally thought. For example, the committee pointed out that more than 80% of the polychlorinated biphenyls (PCBs) in Lake Superior fall from the skies.

Thus, it's quite understandable why reducing industrial discharges has had such a meager effect: Such wastes, Loucks says, are "an awfully small part of the picture." And controlling emissions into groundwater and air is a far more difficult undertaking.

Loucks, who heads Holcomb Research Institute at Butler University, served as one of the cochairmen of the binational study committee, along with environmental scientist Henry A. Regier of the University of Toronto. The main purpose of the committee was to assess whether the Great Lakes Water Quality Agreement is still adequate. The agreement, first signed by the U.S. and Canada in 1972 and strengthened in 1978, spells out objectives for improving the quality of Great Lakes water. It also authorizes several cooperative programs and coordinating groups for achieving these goals.

The 1978 revision of the agreement strongly emphasized reducing the levels of toxic chemicals such as DDT and PCBs. When those pollutants came under more strict controls in the 1970s, Loucks says, there was a "certain amount of immediate impact." Nevertheless, the concentrations of those compounds in the food chain have remained relatively constant or declined only slightly since 1978, according to studies cited by the committee.



Sulfur/ketone photomicrograph wins first prize

This photomicrograph of a heterogeneous mixture of sulfur and ketone, magnified 26 times, recently won first prize in the black-and-white light microscopy category at Polaroid Corp.'s fourth annual International Instant Photomicrography Competition. The photograph was taken by William E. Schadel of Raleigh, N.C., using a Nikon polarizing microscope and Nikon 35-mm camera. Winners also were selected in three other categories—electron microscopy, color light microscopy, and photographs taken with instant color slide film. All the first-prize winners received printing systems for making prints from 35-mm slides or $1500 cash awards. Some 400 images were entered in the competition by scientists, engineers, and amateur photomicrographers from seven countries.

Monitoring programs in both the U.S. and Canada have shown that individual fish caught in the Great Lakes regularly exceed allowable levels of toxic residues. Although toxic contamination of other foods produced in the Great Lakes region is less well documented, PCB levels in Canadian beef have been shown to be much higher in Ontario and Quebec than in the Atlantic or western provinces.

Of particular concern to the committee is a Wisconsin study showing that infants nursing on PCB-contaminated breast milk are receiving daily doses of the toxic chemicals in excess of the maximum allowable levels set for adults by the U.S. Food & Drug Administration.

Although the immediate health effects, if any, of such exposures are unclear, the committee expressed strong concern about the possible long-term effects of exposure to and accumulation of toxic compounds. In the case of infants' exposure to PCBs, the committee called for long-term epidemiological studies to assess possible increased cancer risks or other health effects.

The picture of Great Lakes pollution isn't painted entirely in blacks and grays, though. The committee notes that major progress has been made in reducing phosphate levels in the lakes. "Those waters that were severely enriched [in phosphates] are showing signs of recovery," it says. Also evident are lower levels of heavy-metal ions, some persistent pesticides, and some industrial organic chemicals from point sources.

Even though phosphate levels have been driven down, many species of aquatic life in the lakes "remain stressed," the committee found, and further reductions are necessary. Phosphate pollution caused by municipal sewage and by use of fertilizers, detergents, and other products can lead to the proliferation of algae and other plants because phosphorus is a basic plant nutrient. Overabundance of algae, in turn, can deplete oxygen in the lake water, leading to stress and consequent loss of certain species of fish.

Most PCBs in Lake Superior come from atmosphere

Source	Kg per year	% of total
Atmosphere	6600–8300	82–86%
Tributary	1300	13–16
Municipal discharges	66	1
Industrial discharges	2	1
Total	**8000–9000**	

Source: Steven J. Eisenreich, University of Minnesota, Minneapolis.

Most of the progress so far in limiting the introduction of phosphates into the lakes has come through improved control of point sources, especially municipal sewage facilities. "Increased investment in municipal sewage-treatment plants," the committee says, "is the major success story of the phosphorus control programs of the 1972 and 1978 agreements."

Nevertheless, the committee points out that relatively few concrete corrective measures have been implemented to reduce other types of toxic pollution in the Great Lakes. It calls on the states and provinces bordering the lakes and on the two federal governments to face the challenge by developing a comprehensive strategy for managing toxic substances. Such a strategy, it notes, should include an inventory of all sources of toxic chemicals of concern within the Great Lakes ecosystem, actions to prevent leaking of toxic compounds from landfills, and better management of toxic waste through siting and operation of modern treatment centers in all regions of the basin.

To improve accountability in carrying out the water quality agreement, the committee suggests that the U.S. and Canadian governments issue a report every two years on progress achieved and that bilateral meetings be held regularly among senior officials to discuss any problems.

Also urgently needed, according to the committee, is continuity in the planning and funding of interdisciplinary research initiatives aimed at gaining a better understanding of the Great Lakes ecosystem and the connections between chemical contamination, water-level fluctuations, economic development, and fisheries management. □

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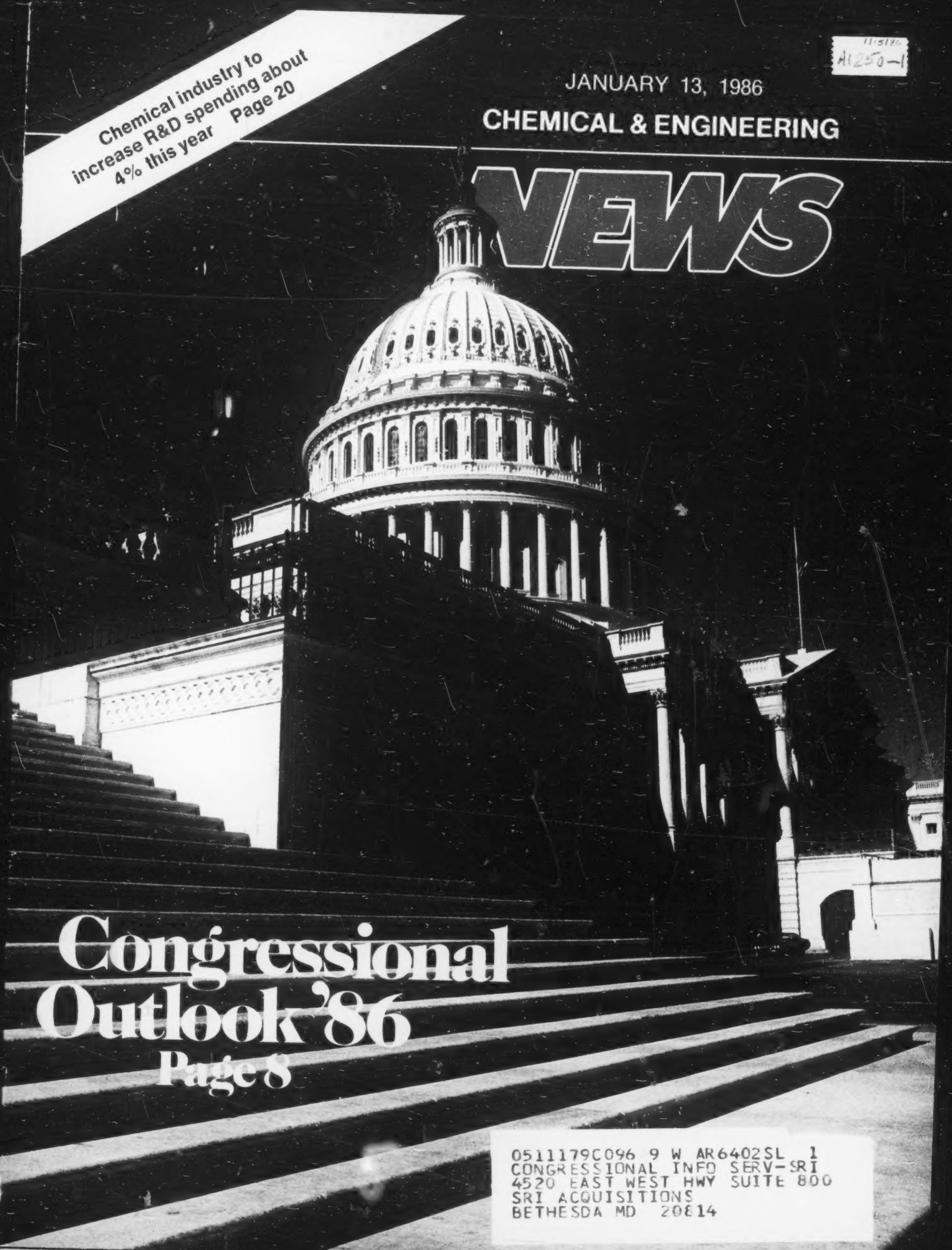
JANUARY 13, 1986

CHEMICAL & ENGINEERING NEWS



Chemical industry to increase R&D spending about 4% this year Page 20

Congressional Outlook '86

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News of the Week

- **Physical chemist John McTague named acting Presidential science adviser, but scientific community wants permanent leader to safeguard research budgets. Page 4**
- **U.S. and Canadian envoys recommend that U.S. spend $5 billion to develop cheaper coal-cleaning methods to reduce acid rain. Page 5**
- **Union Carbide successfully eludes GAF takeover. Page 5**
- **Ruling on site of Carbide/India suit to be made soon. Page 5**
- **Chemical industry adjustments in 1985 to recover from recession may lead to better performance in 1986, CMA survey indicates. Page 6**
- **Accident at Oklahoma uranium processing facility leaves one person dead, some 30 injured. Page 6**

Business

The U.S. chemical industry's R&D spending will rise only 4% from that of 1985; although development of higher-value products is a desired goal, low profitability curbs spending. **Page 20**

Government

Problems of competition in commercialization of space technology foreseen in OECD report on trade-related issues of space. **Page 30**

Science

Spectroscopy techniques in subpicosecond times allow chemists to study excited molecules directly. **Page 36**

Demographic trends have less effect on the supply of scientists and engineers than do career choices and market forces. **Page 38**

American Chemical Society will begin publishing a new journal on energy and fuels research in January 1987. **Page 40**

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"Diet-Related Diseases: The Modern Epidemic" describes various toxic and biologically active substances in foods. **Page 41**

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News Focus

Much that Congress does in the upcoming session, including decisions on R&D funding, will be restricted by law to reduce the federal deficit. Page 8

Chemical Industry Will Spend Just 4% More on R&D in 1986

Companies' need to keep expenditures in line with earnings conflicts with desire to generate new, higher-value products

David Webber, C&EN New York

The chemical industry will boost its spending on research and development in 1986 by the smallest amount in years. A group of 13 companies with the largest chemical research programs plans to increase its R&D outlays by a composite total of just 4% next year, putting an end to an eight-year period marked by double-digit budget growth in every year except 1983, the year immediately following the end of the most recent recession.

The small size of the planned spending increase also means that R&D expenditures by the group of firms actually will decline in 1986 when adjusted for inflation. In constant dollars (1972 = 100), outlays will fall back about 1% this year compared with 1985's outlays.

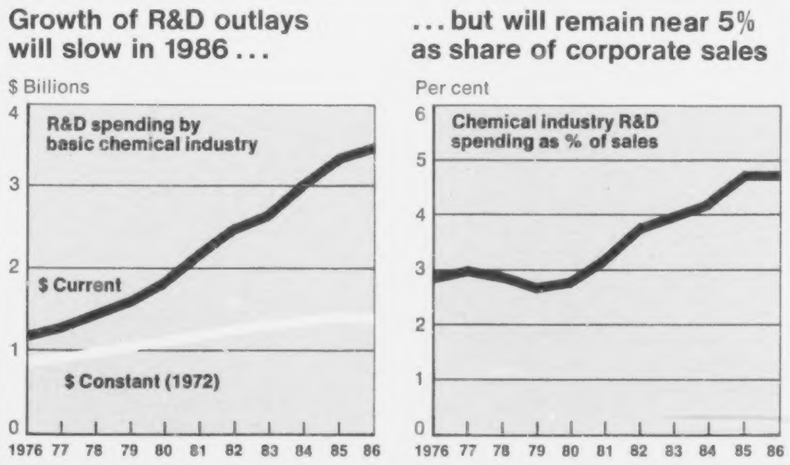
The industry is curbing the growth of its research spending at the very time that R&D is assuming the key position in most companies' strategic planning. The generation of new, higher-value products through enhanced, more market-oriented R&D programs is widely considered a major part of the answer to the problems posed to U.S. producers by the increasingly global chemical marketplace. But the industry is also in a period of retrenchment touched off by the poor profitability of many operations in 1985. The effort to slash costs has been characterized most notably over the past 12 months by deep cuts in many firms' salaried work forces, reductions that have affected R&D workers.

At Du Pont, the perennial leader in chemical R&D expenditures, retrenchment in the form of a massive early retirement program a year ago and continuing curtailment of research in what the company considers mature businesses has led to a sharp reduction in spending plans for 1986. Not only did the company, which had predicted a 10% boost in R&D funding for 1985, end up adding just 8% in 1985, it now intends to cut back outlays 5% this year. Traditionally, Du Pont's R&D budget has accounted for about a third of the group's research spending. Even though that share will fall under 30% in 1986, it is still large enough to skew the group's composite totals.

The slowing of R&D spending growth does not stem entirely from retrenchment. Some companies, such as PPG Industries, invested large increments of cash last year to launch new programs. Subsequent spending increases seem smaller by comparison.

Furthermore, the smaller size of the budget increase for 1986 in no way reflects a diminishment of the chemical industry's current strong commitment to research. If just those companies other than Du Pont are considered (Du Pont can be factored out because the size of its work force reduction was extraordinary), R&D spending will rise a composite 7% in 1986. Although budget growth is still lower, the planned 7% increase for the non-Du Pont group is still greater than the sales growth of 5% or so that is anticipated for chemicals in 1986. As a result, R&D spending is reaching record heights as a share of sales. That measure, often considered a good, if rough, indicator of the relative importance of research to a company, did not reach a composite 4% for the group until 1983. In 1985, it rose to 4.8% and is likely to remain more or less on the same plateau this year as well.

The chemical companies' R&D budget decisions fit into the general pattern of research spending by


Growth of R&D outlays will slow in 1986 . . .

. . . but will remain near 5% as share of corporate sales

Note: For companies listed on page 21.
Sources: C&EN surveys and estimates, Battelle Columbus Laboratories

Smallest R&D spending increase of decade planned for 1986

$ Millions	Planned 1986	Actual 1985	Planned 1985	1984	1983	1982	1981	1980	Change from previous year		R&D spending as % of sales	
									1986	1985	1985	1984
Air Products[a]	$ 60	$ 51	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	18%	16%	2.8%	2.5%
American Cyanamid	265	250	250	237	215	190	172	148	6	5	7.1	6.1
Celanese	105	100	105	94	85	100	104	94	5	6	3.3	2.8
Dow Chemical	600	550	530	507	492	460	404	314	9	8	4.8	4.4
Du Pont[b]	1030	1080	1100	1000	875	775	647	591	−5	8	7.2	6.3
Ethyl	46	46	42	40	39	39	37	34	0	15	3.0	2.4
W. R. Grace	95	90	90	79	71	62	55	45	6	14	1.3	1.2
Hercules[c]	77	75	79	72	74	74	65	57	3	4	2.9	2.8
Monsanto	600	525	450	370	290	264	233	208	14	42	7.5	5.5
Olin	59	59	53	54	51	47	39	31	0	9	3.3	2.6
PPG Industries	188	185	185	150	127	127	119	103	2	23	4.3	3.5
Rohm & Haas	128	120	120	109	100	92	77	67	7	10	5.7	5.3
Union Carbide	265[d]	265	280	265	245	240	207	166	0	0	3.0	2.8
TOTAL	**$3518**	**$3396**	**$3335**	**$3021**	**$2704**	**$2507**	**$2191**	**$1888**			**4.8%**	**4.2%**
ANNUAL CHANGE	**4%**	**12%**	**10%**	**12%**	**8%**	**14%**	**16%**	**16%**				

a Figures are for fiscal year ending Sept. 30. b All figures exclude Conoco. c Figures up to and including most of 1983 include polypropylene-related R&D. Since November 1983 polypropylene R&D has been part of Himont joint venture. d Estimate. na = not available.

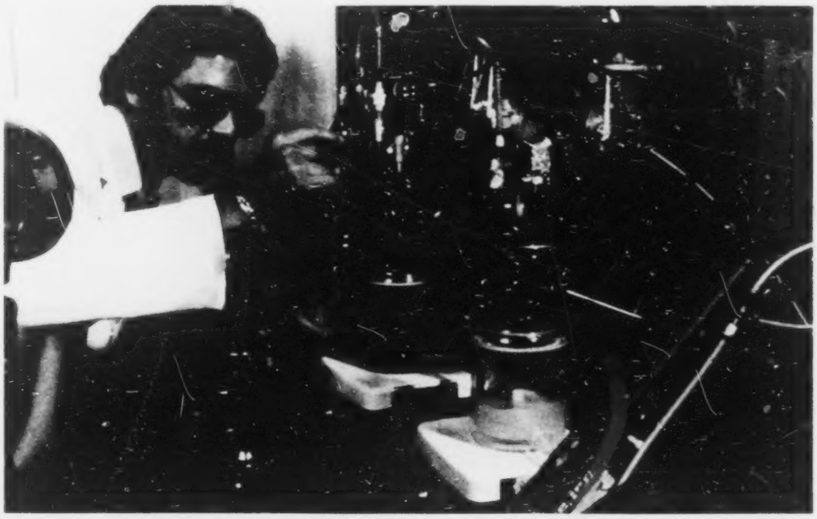
all U.S. industries. Company-funded R&D investment is expected to grow about 9% next year after a 12% increase in 1985, according to a National Science Foundation survey. The survey found that the cutback in growth resulted from uncertainty on the part of corporate management about this year's economic outlook. Member companies of the survey sample, which account for 53% of all U.S. company-funded R&D expenditures, said they were unsure how lower interest rates, the strength of the dollar, the rise of imports, and the increase of overseas competition would affect sales and earnings this year.

According to NSF, spending on chemicals and allied products research, which includes the pharmaceutical industry, will rise 10% this year. The smaller industrial chemicals segment will boost spending just 9%. The survey, however, was conducted in mid-1985, when executives might have been more sanguine than now.

Chemicals and allied products R&D spending continues to account for about 16% of all U.S. industrial research outlays. In 1986, NSF predicts chemical R&D expenditures will be $9.5 billion out of total U.S. industrial research funding of $57.8 billion. Only two industrial segments—machinery and electrical equipment—will spend more on research than the chemical industry. According to the survey, the machinery industry will spend $10.9 billion on R&D this year, and the electrical equipment industry $10.7 billion.

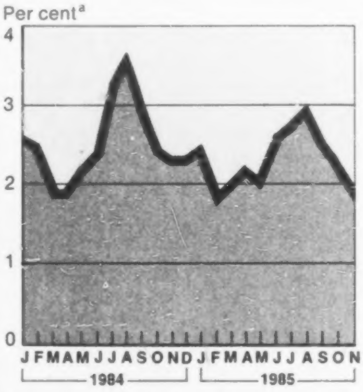
R&D spending in other segments will be motor vehicles and motor vehicles equipment, $6.3 billion; professional and scientific instruments, $4.9 billion; aircraft, $4.8 billion; and all others, $10.7 billion. In 1985, company-funded research in the U.S. totaled $53.2 billion. Last year's list was led by the electrical equipment industry at $10.0 billion, followed by machinery, $9.8 billion; chemicals and allied products, $8.6 billion; motor vehicles and motor vehicles equipment, $5.9 billion; professional and scientific instruments, $4.6 billion; aircraft, $4.4 billion; and all others, $9.9 billion.

Also, despite being smaller, chemical R&D spending in 1986 will maintain a long-term trend toward an ever-larger research component in the chemical industry's future-oriented spending (capital spending plus R&D spending). The trend reflects the industry's overall shift



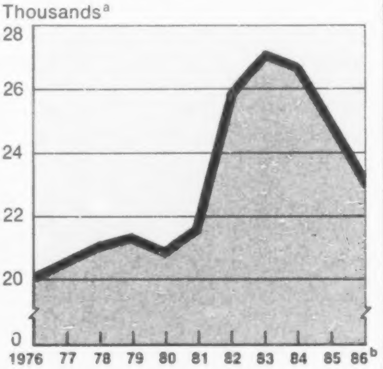
Air Products research worker tests bacterial cultures

Although professional unemployment declines . . .



a Unemployment rate for professional specialty employees, including engineers, mathematical and computer scientists, natural scientists, health diagnosing occupations, health assessment and treating occupations, teachers, lawyers, and judges. Not seasonally adjusted.
Source: Bureau of Labor Statistics

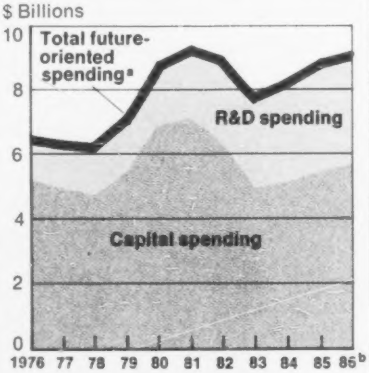
. . . the chemical industry employs fewer researchers



a Full-time equivalent R&D scientists and engineers in basic chemical industry at the beginning of the year. **b** Estimate. **Sources:** National Science Foundation, C&EN estimate

in emphasis from high volume to high-value-added products. As a result, between 1976 and 1986, composite R&D spending for the group of 13 companies tracked by C&EN has grown at an annual rate of 12%, more than tripling from $1.2 billion in 1976 to a projected $3.7 billion this year. Capital spending for the same group, on the other hand, features a 10-year annual compound growth average of just 0.6%. The group's capital outlays peaked at $7.1 billion in 1981; this year it likely will total about $5.6 billion. In another way of looking at it, R&D spending, which accounted for just 18% of chemical future-oriented expenditures in 1976, will account for about 40% of such outlays this year.

R&D takes growing share of future-oriented spending



a Total R&D and capital spending for chemical companies listed on page 21. **b** C&EN estimates

Within the group of companies surveyed, Air Products plans to boost its R&D spending by the highest percentage next year. The company, which had the highest profit margin of any of the 15 largest chemical firms over the first nine months of 1985, will lay out $60 million on R&D this fiscal year (ending Sept. 30), up 18% from fiscal 1985, which was up 16% from fiscal 1984. The fiscal 1986 forecast does not include an estimated $20 million worth of customer-funded R&D that the company will undertake.

The Allentown, Pa.-based company intends to divide some 80% of this year's R&D budget between new technology initiatives in its four core areas—air separation, polymer and amine chemistry, catalysis, and inorganics—and technology diversification into electronics, ceramics, microbiology, and noncryogenic separation. The remainder will be devoted to improving existing technologies in the core businesses.

Monsanto is the only other company planning a double-digit increase this year; it expects to expand its 1985 R&D expenditures of between $500 million and $550 million to between $550 million and $650 million this year, or about 14% based on the range midpoints. Monsanto data show a 42% leap in R&D spending between 1984 and 1985, but $75 million to $150 million of last year's increase is attributable to R&D carried out by G. D. Searle.

Without the acquisition, 1985 R&D spending would have risen to between $400 million to $425 million, a spokeswoman says, up 22% and below the $450 million the company forecast at this time last year. Of this year's total research outlays, she says, non-Searle activities will account for $450 million to $500 million, meaning the actual increase could be as low as 6% and as high as 25%. Calculating from the range midpoints, non-Searle R&D spending will rise 15%.

Monsanto is still weighing the final size of this year's R&D budget, chief executive Richard D. Mahoney noted at a press luncheon last week. The company, which has been accused by some analysts of spending too lavishly on R&D, is cutting back in some areas. Some long-term plant growth regulator work has been terminated already, and Mahoney plans to prune the health care project list as well.

The acquisition of Searle, however, means that 1986 probably will be the year in which Monsanto spends as much as Dow Chemical. (As recently as 1983 Monsanto spent less than 60% as much on R&D as did Dow.) Dow has set aside about $600 million for R&D in 1986.

One of the sharpest declines in funding growth will be at PPG, which, after raising its R&D outlays 23% in 1985, will add just 2% to its budget in 1986. The explanation, however, is the large, initial funding last year for PPG's new collaborative biotechnology program with the Research Institute of Scripps Clinic in La Jolla, Calif.

The increases in R&D spending by the group of 13 chemical firms in 1985 meant that the portion of sales dollars devoted to research rose at every member of the group last year. Climbing to the top of the list from third in 1984 was Monsanto, where the R&D spending-to-sales ratio jumped to 7.5% from 5.5%. Next highest was American Cyanamid at 7.1%, up from 6.1% the year before. Following was Rohm & Haas at 5.7%, up from 5.3% in 1984. □

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Commercial Detergents

Technical service is key for surfactant makers

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NEWS

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News of the Week

- **Research programs of federal agencies will be squeezed by cuts to reduce the budget deficit. Page 4**
- **Philadelphians protest proposal to incinerate chemical wastes in ocean off Delaware Bay. Page 5**
- **Man-made trace gases are changing the chemical composition of the atmosphere but their effects on climate and temperature are not understood. Page 5**
- **White House Science Council report calls for stepup in funding of academic science, tax incentives for firms that support university research. Page 6**
- **EPA proposes rules to control landfill disposal of wastes containing organic solvents, dioxins. Page 6**

Cover: Photo courtesy of BASF Chemicals

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Business

Biotechnology stock values surged in 1985, providing more options to companies seeking funding. **Page 8**

Consumption of engineering resins expected to grow to 4.8 billion lb in 1991 worldwide, 1.78 billion lb in U.S. **Page 10**

International Business

Pesticide subsidies to Third World countries may be having negative economic and ecological effects, says report. **Page 11**

Government

Thanks to preferential treatment by Congress, specific universities have received funding—a practice frowned on by many. **Page 14**

Clean Sites Inc. speeds up progress in cleaning hazardous waste sites with believed record-fast action in North Carolina. **Page 15**

Science

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Technology

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Official reports from December meeting of ACS Board of Directors update details of committee activities. **Page 54**

Product Report

Makers of detergent surfactants for the highly fragmented industrial and institutional market must set up technical service systems to compete. Page 21

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FEDERAL R&D BUDGETS: Deficit law will cut expenditures

The first step down the path to automatic budget cuts aimed at reducing the federal deficit was taken last week when the Office of Management & Budget and the Congressional Budget Office submitted their "Sequestration Report for Fiscal 1986" to the U.S. Comptroller General.

The report details the cuts necessary to reduce the estimated fiscal 1986 deficit of $220.5 billion by $11.7 billion. Most line items in the defense budget are cut back 4.9%, those in the nondefense budget 4.3%. Between them, Congress and the President exempted many budget items from the cuts.

Research, however, is not among the exempted programs. It is an inescapable fact that federal research program managers are going to have less money to spend in fiscal 1986 than they thought they would have when the fiscal year began. Some agencies, like the National Institutes of Health and the Department of Defense, still will have more research money to spend in fiscal 1986 than they had in fiscal 1985 because Congress gave them fairly large budget increases. However, other agencies, such as the National Science Foundation, will be below fiscal 1985 funding levels because Congress gave them either small or no budget increases.

NSF's basic strategy in implementing the automatic cuts will be to protect its prior commitments. By implication, that means that people who already have received their new grants or grant increases are in reasonably good shape, says Edward F. Hayes, head of NSF's chemistry division. Most of the strain will come, he says, in the area of competitively reviewed proposals. NSF says it will do its best to minimize any reduction in the number of proposals it funds. However, that means that the awards may be smaller than they would have been and that the increases NSF can provide for renewals will be limited. The agency probably will try to save some money by delaying the obligation of funds for instrumentation into the second or third year of a grant in cases where it is possible to do so.

Even before the budget cuts, the Department of Energy's research budget was down in 1986, but now it will be reduced even further. The automatic cuts will have the most serious impact on DOE's national laboratories, according to Elliot S. Pierce, director of the division of chemical sciences, "because, although we did send out money to them, we are now going to have to pull some of it back." And, he adds, "we will have to reduce the money that we will be sending out to universities for the rest of the year."

OMB and CBO's figures are now being checked by the General Accounting Office, which has to forward them to President Reagan by Jan. 21. He is to sign a sequestration order for the cuts on Feb. 1. The reductions will take effect on March 1, unless Congress comes up with a different package of cuts by then—an unlikely prospect. As painful as this first round of automatic reductions will be, the prospects for fiscal 1987 are even worse. The current round of cuts supposedly would reduce the 1986 deficit to $208.8 billion. For fiscal 1987, the mandatory target is $144 billion. □

Cuts wipe out R&D budget gains

	1986				
$ Millions	Final funding[a]	Enacted by Congress	Proposed by Administration	1985 funding	% change 1985–86
DOD	**$33,493.3**	**$35,219.0**	**$39,176.6**	**$31,128.0**	**11%**
Air Force	13,046.0	13,718.2	15,578.5	13,424.1	−3
Navy	9,572.0	10,065.2	11,264.3	9,172.6	4
Army	4,563.1	4,798.2	5,279.9	4,349.0	5
Defense agencies	6,312.2	6,637.4	7,053.9	4,182.3	51
NIH	**5,257.7**	**5,493.9**	**4,860.5**	**5,148.2**	**2**
DOE	**3,679.4**	**3,849.0**	**4,044.1**	**3,989.9**	**−8**
Energy supply R&D	1,696.1	1,772.3	1,971.0	1,957.8	−14
Weapons R&D	1,051.4	1,065.3	1,211.6	1,027.2	−2
General science & research	655.9	685.4	685.5	730.0	−11
Fossil R&D	312.0	326.0	176.0	274.9	13
NASA R&D	**2,638.3**	**2,756.8**	**2,881.8**	**2,462.6**	**7**
NSF	**1,458.3**	**1,523.8**	**1,571.2**	**1,501.6**	**−3**
Commerce	**1,199.9**	**1,253.8**	**1,056.8**	**1,362.3**	**−12**
NOAA	1,083.2	1,131.9	948.8	1,239.2	−13
NBS	116.7	121.9	108.0	123.1	−5
USDA	**894.3**	**934.5**	**870.4**	**942.4**	**−5**
EPA R&D	**213.8**	**223.4**	**212.4**	**188.9**	**13**
TOTAL	$48,835.0	$51,254.2	$54,673.8	$46,723.9	4%

[a] After application of automatic budget reductions.

Biotechnology Stock Strength Could Help Firms Attract Funds

Stock values soared in 1985, outperforming the market; biotechnology companies now have more options in their quest for financing

David Webber, C&EN New York

Biotechnology stocks regained the confidence of the investment community in a big way last year. Prices surged on a broad front, especially during the fourth quarter, eclipsing the rise of the overall stock market by a wide margin. As a result, small biotechnology-based companies looking for new financing, which has been restricted largely to private equity placements and joint venturing for the past two years, may now consider looking for investors once again where many of the firms raised their grubstakes: the public marketplace.

Over the course of 1985, the composite market value—the product of stock price and number of shares of common stock outstanding—of a group of 12 biotechnology-based companies soared 121%. During the same period (Dec. 28, 1984, to Dec. 27, 1985), the Standard & Poor's 400 industrials stock index climbed 28%. Much of the surge achieved by the biotechnology stocks—which reflect a cross section of firms involved in recombinant DNA technology, hybridoma-based technology, and support businesses in instruments and other materials—came during the fall. By mid-September, C&EN's biotechnology stock index had risen 35%. Between then and the end of the year, it rocketed another 64%. By comparison, the S&P 400 industrials index rose just 15% over the same 14 final weeks of the year.

C&EN's biotechnology stock index is based on the stock prices for Amgen, Applied Biosystems, Biogen, Centocor, Cetus, Damon Biotech, Genentech, Genetic Systems, Genex, Hybritech, Molecular Genetics, and Monoclonal Antibodies. To reflect developments in the biotechnology area, several firms will be deleted and several will be added to the company sample for the next report on biotechnology stocks.

To a certain extent, the general trend of any reasonably small biotechnology stock index at this point reflects the movement of Genentech stock prices. The South San Francisco company has a market value so much higher than any of its competitors', it strongly influences any interpretation of the market's direction. Nonetheless, Genentech's own good performance on the stock market in 1985 was not the only reason the index increased so sharply. Stock price gains—and large ones—were almost universal in the biotechnology area last year.

For instance, of 17 companies with some of the highest market values in the area (an enlarged version of the sample of firms used for C&EN's biotechnology stock index), all but one recorded rises in stock prices over the course of the year. The prices of eight of the 17 stocks more than doubled in 1985, and two more stocks came just short of rising 100%. It was a robust performance nearly across the board.

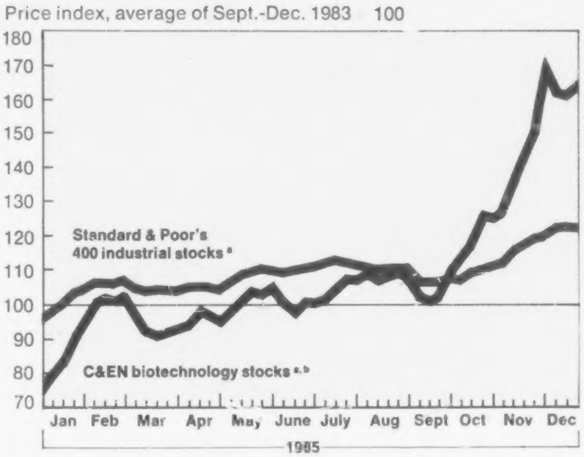
The market's vigor seems to have held into the new year. Between the final Friday in 1985 (Dec. 27) and the second Friday in 1986 (Jan. 10), many biotechnology stock prices rose strongly, notwithstanding the record tumble taken by the Dow Jones Industrials Average on Jan. 7. Genentech stock, for example, shot up to a 52-week record of $76½ before closing at $73¼, up 10% over the two-week period. Monoclonal Antibodies Inc. stock also rose to a 52-week record high price and closed at $19½, up 15% during the period. One-year highs were also notched by California Biotechnology stock, which jumped 35% to $17¼, and by DNA Plant Technology stock, which rose a more modest 8% to $11¼. In other notable increases, per-share prices rose 18% for Biogen and 9% for Chiron over the two-week span.

The continued muscle flexing is especially encouraging to some analysts, because it seems to echo January rallies in two previous years that set the tone for the next 11 months. In 1985, for example, the biotechnology stock index climbed 38% over the first six weeks of the year. Analysts hope the pattern repeats itself.

The surge comes at a fortunate time for many in the biotechnology area. Since the original bull market for biotechnology issues ended in 1983, the small companies have been forced to seek additional financing outside the stock market. Now many firms, having already dug deeply into the mounds of cash piled up during the first burst of enthusiasm for biotechnology, face the high costs of clinical trials, manufacturing scaleup, and the establishment of a marketing force. Most observers believe that access to capital in the coming period will determine whether companies remain in business, whether they remain independent, and what kind of operation they can become.

"We may see a more favorable financial environment with more interest in the biotechnology companies on the part of institutional investors this year," says Linda I. Miller, an analyst at Paine Webber.

Biotechnology stocks outran the booming stock market in fourth quarter . . .



a Reindexed to average for Sept.-Dec. 1983 period to show relative change. Prices as of Friday close each week. b Based on stock prices for Amgen, Applied Biosystems, Biogen, Centocor, Cetus, Damon Biotech, Genentech, Genetic Systems, Genex, Hybritech, Molecular Genetics, and Monoclonal Antibodies.

. . . and the value of many stocks more than doubled during the year

Company	Recent price[a]	% change[b]	52-week range	
			High	Low
Amgen	$13⅝	187%	$15¾	$ 4½
Applied Biosystems[c]	29⅜	103	30⅞	13⅜
Biogen	14⅜	161	18⅝	4¾
Bio-Response	7⅛	78	9⅜	3¾
California Biotechnology	12¾	132	15	5½
Centocor	23½	169	27¼	8¼
Cetus	28⅛	213	33⅜	8⅝
Chiron	12½	186	15⅛	4¼
Collaborative Research	5⅛	17	7⅛	2¾
Damon Biotech	8⅛	76	9¼	4⅛
DNA Plant Technology	10⅜	196	11¼	3⅜
Genentech	66⅝	97	75¼	33¾
Genetic Systems[d]	10	86	10⅜	5
Genex	1¾	−67	7¾	1⅜
Hybritech[e]	30¾	92	32	15¾
Molecular Genetics	10¾	43	13	6⅛
Monoclonal Antibodies	17	89	19¼	7¾

a As of close on Friday, Dec. 27, 1985. b Dec. 28, 1984, to Dec. 27, 1985. c Adjusted for 2-for-1 stock split in March 1985. d To be acquired by Bristol-Myers, pending shareholder approval. e To be acquired by Eli Lilly, pending shareholder approval.

"There is more confidence now that the industry can deliver."

Seeking to exploit the renewed attractiveness of biotechnology stocks, two companies already have returned to the public market for financing. Centocor, Malvern, Pa., tested the water first, making a public offering of 1 million shares of common stock in December. The offering sold out at $22.50 per share. Centocor, which last fall was frequently mentioned as a takeover candidate, perhaps whetted the appetites of investors. The firm says it will use the proceeds of the offering for working capital requirements including therapeutic product development, facilities expansion, and the proposed purchase of the assets of one of its R&D limited partnerships.

Also in December, Damon Biotech, Needham Heights, Mass., announced that it had filed a registration statement for a public offering of 2.5 million shares of common stock. The company is still waiting for the Securities & Exchange Commission to approve the offering. Word is expected by the end of the month, a spokesman says.

Analysts expect other companies—Chiron and California Biotechnology are rumored as likely ones—to make new offerings, too.

How deeply the stock market can be mined by the biotechnology companies this time around depends both on stock performance in the coming months and on how the individual operations are perceived by potential investors. In a way, the second factor has not yet been as important as might be expected. The broad rise of biotechnology stock prices last fall was sparked by individual developments—acquisition agreements for Hybritech and Genetic Systems, FDA approval of Genentech's human growth hormone, promising results in trials of interleukin-2—but the effect seemed to manifest itself in a general fashion.

How much more stock prices will rise, if at all, depends on a number of factors. Analysts do not believe that the market will need more acquisitions on the order of those planned for Hybritech and Genetic Systems (neither has been concluded yet) to catalyze continued price increases.

"I don't know if we need more acquisitions to keep stocks up, but the acquisitions showed that there is a safety net to biotechnology investment," Miller points out. "The technology itself is of value. This was demonstrated by the acquisitions by large companies. There is now much less risk in participating in a small company. Even if no money is made on products, value has been created."

Nonetheless, success in product development will determine the best investment candidates this year, analysts tend to believe. "One thing that makes me optimistic is that we can continue to expect good news from a variety of sources," comments Parag Saxena, assistant vice president in charge of the emerging health care fund at Citibank. "That will generate interest in the stocks."

According to Miller, "The stocks still have some up side, but whether it's 20% or 200% depends on the individual company." Saxena, too, expects the climb to continue. "The stock index will be at a higher number a year from now," he says.

In this climate of renewed enthusiasm for biotechnology stocks, it may even be possible for private biotechnology firms to go public. "I think the good-quality companies in their segments of the industry should be considering an initial public offering," remarks Miller. "Given the interest in the industry, a lot of them will be considering it. Those companies shut out of the public market one-and-a-half to two years ago should think about it. My guess is that the market would be receptive." □

Good growth forecast for engineering resins

Worldwide consumption of engineering resins will grow at an annual rate of 7% over the next five years to reach 4.8 billion lb in 1991 from 3.2 billion lb in 1986, according to James J. Conway, marketing director of Celanese Engineering Resins. For its own part, Celanese, a major producer of engineering resins, is responding to this growth by developing new resins and building plants and by acquiring technology and businesses. Most recently, the firm introduced a polyimide licensed from the National Aeronautics & Space Administration, introduced a liquid-crystal polyester of its own, bought a British compounder of engineering resins, and started an expansion of its Bishop, Tex., polyacetal plant.

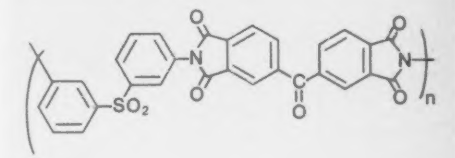
In the U.S., Conway says, engineering resin consumption totaled 1.14 billion lb in 1985, an increase of 3 to 4% over 1984. Those figures include imports and plastic alloys. A slow economy will hold the 1986 rise only 4% to 1.19 billion lb. After 1987, Conway expects a more robust growth in the U.S. to about 1.78 billion lb in 1991.

In this country, the largest outlet for engineering resins is transportation uses, which took 345 million lb in 1985, or 30% of the total. Conway expects such applications to grow 9% per year to reach 590 million lb by 1991, which still will be one third of total engineering resin use. The second largest market is electrical and electronics, which accounted for 285 million lb in 1985, or one fourth of all engineering resins. Growth at 11% per year will lift this segment to 535 million lb in 1991, which will be a 30% share.

Another important market segment is a broad category that includes consumer goods. Conway says that increasing consumer acceptance of engineering resins in packaging and housewares will buoy this market at an annual rate of 7% to 340 million lb in 1991 from 230 million in 1985. Industrial goods consumed 150 million lb of engineering resins in 1985. The industrial market will grow 5% annually to 195 million lb in 1991, Conway says.

The one loser among engineering resin applications is construction, where the 135 million lb of engineering resins used in 1985 will shrink 1.5% per year to 125 million lb in 1991. Celanese managers attribute this decline to market saturation, erosion of the contribution of engineering resins by other plastics, and changes in definitions. Appearance of market saturation and penetration by other plastics will stem any growth in construction applications. A drop in absolute terms will come from reclassification of some construction uses as industrial.

NASA's new polyimides



Engineering resins use topped 3 billion lb in 1985 . . .

Millions of lb[a]	U.S.	Rest of world	Total	% change in total from 1984
Nylons	415	917	1332	5%
Polycarbonate	315	359	674	4
Polyphenylene ether	155	194	349	−2
Thermoplastic polyesters	120	158	278	8
Acetal	118	424	542	6
Polyphenylene sulfide	10	10	20	0
Others[b]	9	5	14	0
TOTAL	1142	2067	3209	4%

. . . and is reaching for 5 billion lb in 1991

Millions of lb	1985	1986	1991	% change 1985–86
U.S.	1142	1190	1780	8%
Japan	677	724	1014	7
Western Europe	1114	1181	1580	6
Other	276	290	410	7
TOTAL	3209	3385	4785	7%

a Includes imports and alloys. b Includes polysulfone, polyarylsulfone, polyether sulfone, polymide, polyetherimide, and polyamide-imide; excludes fluoropolymers and acrylonitrile-butadiene-styrene. Source: Celanese

By a number of recent actions, Celanese is hoping to gain a share of the predicted growth in engineering resins—for instance, production of a NASA-developed polyimide. The polyimide is made from 3,3′,4,4′-benzophenonetetracarboxylic dianhydride and 3,3′-sulfonyldianiline. Celanese Engineering Resins general manager John B. Downard says the company is making it in developmental quantities now, with full commercialization expected in the late 1980s.

The polyimide sulfone (PISO) is part of a series developed at NASA's Langley Research Center, Hampton, Va., by polymer chemist Terry L. St. Clair and David Yamaki, who was then a chemical engineering undergraduate at Massachusetts Institute of Technology. NASA has licensed a similar resin, which uses 3,3′-diaminobenzophenone as the diamine, to Mitsui Toatsu of Japan. That company's U.S. branch imports the product into the U.S. in developmental quantities as a polyamic acid adhesive and laminating varnish, and as fully imidized molding powder and film.

In a further move, Celanese has acquired Whitfield & Son (Plastic Compounders) of Telford, England, from English China Clays. Staff members of the acquired company are experienced in compounding highly specialized engineering plastic formulations for the electrical/electronic, automotive, and consumer/industrial markets. Celanese managers expect that the on-site color matching, formulation, and compounding capabilities of the new, 45,000-sq-ft Telford plant will allow more rapid response to specific customer needs. □

PRODUCT REPORT

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Commercial Detergent Surfactant Makers Rely on Technical Service

Patricia L. Layman, C&EN London

For manufacturers of surfactants, the commercial market—sometimes called the industrial and institutional market or I&I market—is a perplexing one. It is in itself large, but much smaller than its counterpart business in household soaps, detergents, and cleaning products. And it is even more highly fragmented than the household business. In other words, the commercial market is worth selling into, but only after recognizing the special difficulties involved.

Basically this business consists of cleaning products formulated for industrial, commercial, and institutional uses. The major end uses include dry cleaning, commercial dishwashing, commercial laundry, commercial hard-surface cleaners (which comprise cleaners for bath and tile, floors, and metal), carpet cleaning, car washes, and cleaners for the food-processing industry. Thus, the finished-product nature of the business distinguishes it from the classic industrial surfactant business, in which surfactant chemicals tend to be hidden in a process or product and employed as an aid or assist.

The business for commercial products, in fact, is quite similar to that for household soaps, detergents, and cleaning compounds: finished formulations fulfilling the same cleaning functions, but for different locations. The difference, however, is large enough to complicate life for the industry, and for raw material suppliers selling to it.

U.S. sales of such industrial and institutional cleaning products are more than $3 billion per year; that is, sales of finished, formulated products. Surfactants are only a part of that. However, in North America the business consumed some 400 million lb of surfactants of various kinds in 1985, according to estimates by consultants C. A. Houston & Associates, of Mamaroneck, N.Y. Mal-

PPG Industries diversifies into surfactants business

For PPG Industries, getting into the surfactants business has been a decision reflecting a great deal of serious thinking.

"Like so many large chemical concerns, we have been studying our portfolio of businesses, and have decided that diversification into specialties is the way to go," says Robert C. McQueen, surfactants program manager. "But everybody and his brother are doing that."

The company finally decided on specialties after studying the specialties fields open to it and going through an elaborate screening program. Several areas were chosen, one of which was surfactants, says McQueen. PPG saw a technical fit between its process know-how and the technology and requirements for surfactant molecules. This led to the development of the new line of surfactants—anionic sulfonates—it introduced in December.

About two years ago, PPG began its R&D in surfactants at its research center in Barberton, Ohio. The sulfonates are the first fruit of that work, and two other lines are scheduled to follow. One is slated for introduction the middle of this year and the other in 1987. Both of these feature technology related to the sulfonation know-how PPG already has tapped into.

According to McQueen, after investigating the surfactants business, "the thing that intrigued us was the breadth of applications for surfactants. And there had not been that much new technology developed in the past seven to 10 years. We thought we could make a contribution."

The company knows, however, that it can't get there alone. "We will be embarking on a series of acquisitions in the specialty surfactant field" to reach a reasonable size—a critical mass, McQueen says. PPG's work will be strictly with specialty surfactants. "We want to avoid commodity areas. We have no intention of competing, for example, on nonyl phenol ethoxylate, even though we make ethylene oxide."

The first move on the acquisition trail was announced earlier this month when PPG acquired specialty-surfactant supplier Jordan Chemical, of Folcroft, Pa., for an undisclosed sum. PPG management said at the time that the Jordan acquisition would help PPG penetrate the market with its new surfactants and give presence and identity in key market areas.

The company describes its own new surfactants as novel sulfonates. "There have been some isolated references in the literature to them over the past decade, but no one had commercialized them," says McQueen. Admittedly, he adds, they are difficult to manufacture, but PPG can handle the technology. The new line is in the pilot-plant stage in Barberton, and PPG expects to offer commercial quantities by the second quarter of this year.

The new sulfonates are much more stable than sulfates over a wide pH range, from highly acid to highly alkaline, McQueen says. For example, lauryl ether sulfonate is more stable than the lauryl ether sulfate workhorse of shampoos. Under similar conditions, he says, other surfactants come apart and cease to function.

PPG sees a wide range of applications for the new sulfonates. In cosmetics, they may fill a specialty niche in combination with commodity surfactants. The mildness of the sulfonates make such markets an attractive potential. Simply because of economics, however, the sulfonates would not be desirable as the primary surfactant, McQueen points out; they are high-priced specialty items. Also, their compatibility with germicidal actives makes the sulfonates suitable for germicidal hospital scrubs. And their emulsifying properties allow them to be used for a host of industrial applications, from polymerization to agricultural chemical emulsification to enhanced oil recovery.

The materials essentially consist of a sulfonate attached to a polyoxyethylene, with ethoxylation ranging from three to 15 moles of ethylene oxide. Pricing is roughly triple that of the comparable sulfates. "That is why," McQueen says, "we are saying specialty. Downstream a bit, we might be able to close the [price] gap some, but we will never close it completely."

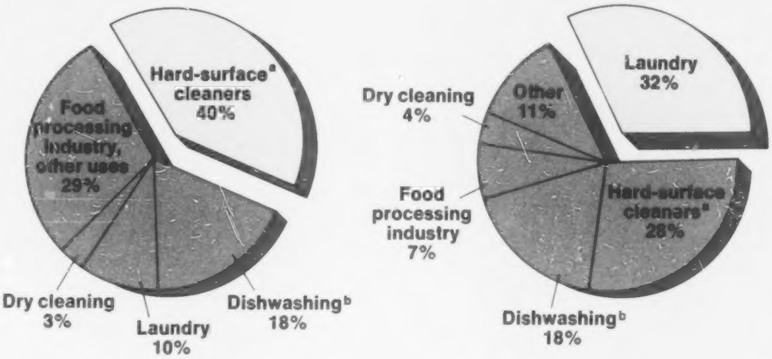
Next in the company's venture into surfactants will be a line of novel quaternary ammonium compounds—both surfactant and biocidal products. The third, low-foam line of surfactants probably will be out in early 1987.

colm McLaughlin, project leader there, says the U.S. market for surfactants in those products is about 360 million lb per year, with another 40 million lb consumed in Canada. In Western Europe, the market for surfactants for such commercial products is about 287 million lb, with a manufacturers' value of about $150 million.

The U.S. market is so much larger because of three market segments—detergents for hard surface cleaning, metal cleaning, and commercial rug cleaning. Those products are used more commonly in the U.S. than in Europe. However, the market for cleaning products for commercial laundries is significantly larger in Western Europe than in the U.S. One reason, explains McLaughlin, is that "there is a larger seasonal hotel and restaurant linen-cleaning business in Europe than in the U.S."

Between 1979 and 1985, revenues for companies selling formulated products aimed at commercial uses averaged 4 to 7% growth per year. But for the second half of the period, growth has been at the lower end of that range. Net earnings for all companies increased only slightly, and they declined for some individual firms. For this business, which considered itself a money-minting industry during the 1960s and 1970s, that has been a bit of a shock.

McLaughlin suggests that though the problems were basically the result of the recession, several other major factors were involved. For example, a strong dollar adversely affected those U.S. companies in the business that have strong overseas operations. And the business has become increasingly more competitive. It is a service industry that has no secrets. All a potential marketer needs is a bit of detergent chemistry—which can come from a friend-



Hard-surface cleaners lead in North America . . .

. . . but in Europe, laundry tops surfactant market

1985 Total commercial surfactant market = 400 million lb

1985 Total commercial surfactant market = 300 million lb

a Includes bath and tile, floors, metal b Includes machine and hand washings.
Source: C. A. Houston & Associates

ly raw materials supplier—and a few contacts. That is a simplification, of course, and doesn't represent the heavy R&D effort and expenditures of the major companies in the business. But it can be quite true of small firms, which slip into the market and serve equally small, and sometimes sizable, customers.

Whatever the reasons, the industry has been troubled—so much so that some formulators are now for sale. The situation is getting better, however. For example, the office building boom is still having an encouraging effect on commercial sales, even if many of those new buildings are unoccupied. Also, the ever-increasing use of carpeting, rather than say, hard tile, boosts the sales of carpet cleaners.

According to the Houston studies, though U.S. and Canadian markets are mature, they will grow 2.5% per year for the remainder of the decade, while still-developing Mexican markets will grow more than 10% per year. In Europe, where the business has slowed some, future growth for commercial and industrial process surfactants is pegged at 2 to 3% per year above gross national product, with earnings rebounding to former good health. The commercial market, which is half of the total European surfactant industry, is expected to grow faster than the industrial-process aid market. Moreover, new business opportunities arise as a result of marketing, environmental, and technical shifts in the various geographical areas.

This almost could be considered a motherhood market; the demand for clean, sanitary public facilities and for fast, efficient products requiring low manpower is increasing. Also, changing consumer habits, particularly for dining, are benefiting the restaurant and hotel trades as well as fast food chains. These are both large consumers of institutional products, and are among several of the market sectors for commercial cleaners expected to show the highest growth over the next five years. Contract and janitorial cleaning of shopping malls, retail stores, and small firms is also benefiting from a reviving economy.

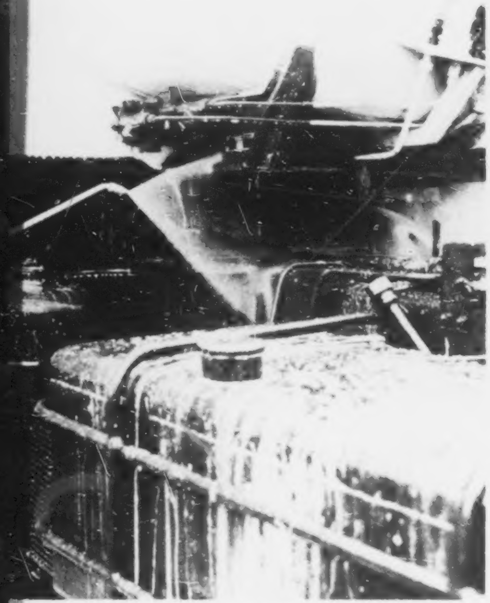
A reviving private economy, however, still has not spilled over to boost public spending, so commercial segments that depend on public allocations—for example, cleaning of schools and colleges, and of hospitals and nursing homes—are still growing slowly, if at all. That is true even though public health concerns are increasing and have the potential to heighten the demand for disinfectant and sanitizer products.

Whatever the market segment, whatever the kinds of products being formulated and sold, one generalization probably describes the industrial and institutional business: It is highly fragmented. There are more than 2000 formulators. Only a few are large, nationally known companies, such as Diversey, a subsidiary of Canadian brewer Molson; Economics Laboratories; DuBois; Chemed; and National Chemsearch. According to some estimates, it is likely that the top 10 companies have less than 50% of the business. Instead, most of the industry consists of small regional or local "mom and pop" operations.

The market is very fragmented in Europe, too. The biggest difference is that the major European household soap and detergent companies—Henkel and Unilever—dominate the commercial business, too. They play a large role, for example, in supplying commercial laundries with formulated products. In the U.S., Procter & Gamble, Colgate, and Lever are in the commercial business hardly at all. However, in other market sectors, such as office cleaning, the European market is even more fragmented than the U.S. market. There are several second-tier leaders, such as Joh. A. Benckaiser, which operates in several countries. But there are few identifiable leaders; the markets tend to split more on a country or regional basis. In fact, looking at the industry worldwide, Henkel is the largest, followed by Diversey, Economics Laboratories (excluding its consumer sales), and Unilever.

Raw material suppliers agree that if anything, the number of companies in the business has not shrunk but expanded. It is easy to get into most commercial businesses. The costs aren't high, and all that's needed is a few tanks, somebody to mix, and some know-how in operating with specialty chemicals. For example, Diversey helped build its business by buying units from companies more accustomed to raw material and intermediate chemical production. It bought an industrial machine dishwashing business from U.K. chemicals producer Albright & Wilson, the Wyandotte commercial laundry business from BASF, and the metal-industry cleaning business from West German chemicals giant Hoechst.

Observes a Diversey executive,



Vehicle being cleaned with Henkel's environmentally safe detergent P3-grato 12 at Frankfurt Airport

"These large companies sold willingly, recognizing that it is far more advantageous for them to supply raw materials to Diversey and leave the solving of the cleaning problems of many thousands of customers to us and to firms specializing in specialty cleaning chemicals as we do. Removing the tea stains from the cups in a cafeteria at the end of Brighton Pier is a long way to go to sell 50 kilos of product."

Just as suppliers tend to shake their heads in wonder at the number of formulating companies in the business, they also comment on the thousands of products that are made. Diversey, for example, sells more than 3000 products into its six major target markets. Most formulated products aimed at industry and institutions are highly specific and small volume.

Like the products sold in the various markets, the raw material suppliers to the industry are many and varied. That can complicate things for suppliers.

For example, selling into the commercial business is different from selling into the household business. Says one supplier: "The linear alkylbenzene sulfonate sold to the household soap and detergent industry would be sold on a long-term contract basis, but industrial and institution purchasing tends to be on a bid-awarding basis."

Major producers of surfactants—companies such as Vista Chemical, Union Carbide, Shell, and Monsanto—serve the commercial business, but more or less as an addendum to the bulk of their sales, which go into the household soap and detergent business. One of the major advantages they have in most of their operations, dealing with an equally large supplier, is lost in an industry of 2000 customers, most of whom are small. So smaller suppliers of surfactants and other raw materials have found the commercial business a lucrative market, one in which personal contact is important, and one in which specialty products can win the day. That leaves things wide open for companies willing to do the specialty work, or whose products lend themselves to the particular needs of industrial and institutional products—suppliers such as BASF Corp.'s chemical division, Witco, Rohm & Haas, GAF, Emery, and newcomers such as PPG Industries. Customers can be extremely loyal to that kind of service; it is not unusual for suppliers to have customers for 20 years or longer.

Small customers frequently turn to their suppliers for help with formulations and other technical services, which might be thought a more natural strength of large surfactant suppliers. However, the assistance large suppliers offer all too frequently concentrates on commodity surfactants, not on the specialty products needed in the commercial business. Moreover, the major companies serving the commercial business, such as Chemed, DuBois, Economics Laboratories, and Diversey, all provide service, anyway.

Chemical raw materials suppliers selling into the business, then, must use different sales aids, offering complete packages of surfactants and other formulation ingredients. They also must work hard to develop effective distribution/distributor networks.

Notes one supplier, "You have to take a sales and distribution outlook on this. We sell directly to the top companies in the industrial and institutional business, but most of our sales are through our distribution network. That entails educating our distributors just like we would the major customers. Our distributors have to give the technical service, too. And of course, we have to do all this at a competitive price."

Large- and small-volume raw materials also can pose problems for suppliers. In an industry where 500,000 lb can be considered a major order, companies tend to devote most of their attention and technical service in-house to the major product lines. Smaller-volume products are, in turn, passed along to the distributors, who must supply such information as the different formulations a supplier is currently recommending, under which conditions each might be recommended, and what other factors are important.

But all that is nothing new to the actual marketers of commercial products, who face almost identical problems with sales, distribution, and technical service, whether in the U.S. or in Europe. For them, the notion of "package" is becoming increasingly important—almost to the point of necessity.

Systems, of course, have been the talk if not the practice of the commercial business for years. For example, Stauffer was touting systems—dispensing systems and cleaning formulations—for the commercial dishwashing industry in the early 1970s, when it was still in that business. But now systems have moved from the discussion stage to become part of life.

As one marketer at Henkel, the Düsseldorf-based chemical products manufacturer, puts it, "We are selling a package deal: the product, the service, the equipment, the know-how." In some areas, such packages are especially crucial. A Henkel product developer adds that "in dishwashing, without automatic dispensing systems, you couldn't sell 1 kilo of product. All our competitors have [automatic systems]—it is the state of the art—so now it depends on who has the better systems."

"It is a service approach. We must be a consultant," says one marketer. "It is not necessarily that we have products better in composition, but better in application. We want to know more about application than the customer does. We are problem solvers." Explaining the rationale behind his thinking, he adds, "Selling a package deal creates a certain dependency for customers. They can't substitute chemicals so easily."

Henkel's marketers would agree. "The important thing to get away from is consumer-products thinking," says one. "We are selling chemicals and solutions, not just products. In the industrial and institutional business, we need to put across the idea, 'If I change Henkel products, I change my entire system, and I can't afford to do that.' "

Much of that comes down to a recognition that, for selling in the industrial and institutional market, the critical factor is cost-performance ratios. In the household-products sector, on the other hand, selling is based on a number of other benefits. Marketers, for example, can advertise benefits such as softness. The inability to do that serves only to intensify the competition within the commercial business.

Meeting the competitive demands can be an expensive business, but marketers deem it worthwhile. What helps is in-house capabilities for equipment design and production. Henkel, for example, has several companies that can do the engineering and construction of dosing and control units for various commercial applications.

Within the past several years, Diversey acquired Beta Co. in Santa Cruz, Calif., for making dispensing equipment. The acquisition was necessary, Diversey marketers say, "to meet the demands of the sophisticated market" of the 1980s. As one marketer explains, "In the 1980s, we found ourselves using microprocessor systems for the automatic cleaning of plants, and machine-dishwashing metering devices incorporating a voice synthesizer that gives instructions to the operator when the detergent or rinse-aid must be replenished or the temperature is falling. Customers now demand and must be given reliable equipment."

Besides, another marketer adds, "We have found the market ready and willing to pay extra money for better and consistent results."

Obviously, even for service-conscious marketers, there is a limit to the amount of service that can be provided. For example, rarely would an on-premise laundry, such as one located in a hotel, be serviced directly by a larger formulator. That would be done by dealers who specialize in looking after this market. They know the basics of the process and can solve a lot of problems directly, or can consult with the formulator. An order of perhaps "3 tons per year would justify direct service from us," says one Henkel marketer.

Similarly, for Henkel's metal-cleaning unit, direct service would be provided with orders of 3 tons or more. Product development staff members point out the sheer logistical problems of working otherwise. In West Germany alone, they say, there are more than 100 direct customers for preanodizing cleaners. Some service and training has to go by the boards.

"We can't train for every single plant," says one researcher there. The company can, however, make sure the customer has access to its expertise in the system, even in metallurgy in its metal-cleaning group. And, on occasion, it has intervened for its customers with their other suppliers—much to the resentment of those suppliers who didn't appreciate their bargaining power suddenly shifting dramatically.

When the company provides training, however, the training accompanies the sale of a system and is given locally, incorporating all the expertise the firm has gathered. What is emphasized and what is recommended would be different, say, in Nigeria than it would be in Japan—different systems are adapted to local markets. This necessity was recognized in the 1970s, when Henkel started regional development, including founding new companies. It has just started a technical training laboratory in Bangkok for its own people and for customers, to serve all Southeast Asia except Japan.

Before, one marketer at Henkel recalls, "We brought our customers here and trained them here. Then when they went back, there was a 'culture' shock. We had to train them for what they would find there—supplies, working conditions, and so on." The local training is also augmented with traveling engineers, company specialists in the various industries. They train both Henkel people and customers, start up new lines, even do market surveys.

What it comes down to, marketers for the commercial business agree, is that they must be able to say truthfully, "We know the markets, and we have the staff." The staff has to be expert in the field, understanding the composition of the various products, how they are supplied, and what they do to the goods being cleaned, as well as how each machine involved functions.

It is difficult for any one company to show strength in all the various commercial segments—there is the danger that its expertise will be spread too thin. The large companies such as Henkel can do it, but they are rare. More commonly, firms specialize.

For example, in its European markets, Lever is particularly strong in commercial textile hygiene. Major competitors within the kitchen hygiene sector include Diversey and Economics Laboratories. In the field of hospital disinfectants and sanitizers, Chemed in the U.S. is especially strong.

Market end uses such as cleaners for the food processing industry, agricultural processing, and metal cleaning are the major industrial part of the business. Cleaning products for the food and beverage industries, for example, would be sold for a variety of applications—dairy; beer, beverages, and bottled water; meat/slaughtering; and can cleaning. Agricultural cleaners include applications such as cow cleaners and sanitizers, and special sanitation uses such as cleaning out chicken houses.

Institutional uses include detergents for laundries, dishwashing, hospital hygiene, and janitorial cleaners.

Each field is, of course, affected by different factors. For example, in the commercial laundry business,

Chemical suppliers are taking hard look at service they provide

The commercial detergent business has always been highly service oriented. Many of the companies that actually sell formulated products also offer service to their customers—for instance, dispensing equipment, employee training programs, and so on.

Similarly, raw material suppliers historically have offered a great deal of service to their customers, the product formulators. This makes it easy for someone to enter the formulator market. As one industry analyst points out, "There is no secret to service. All you need is a bit of detergent chemistry, which if you don't have, you can get from your friendly raw materials supplier, and off you go."

Chemical suppliers provide a variety of sample formulations, for example. And they are also the ones who provide safety and efficacy data when they are needed. That's particularly important for the quaternary ammonium surfactants side of the business, where quaternary ammonium compounds function as biocides for disinfectants and fungicides for hospitals and other institutions, as well as for uses as diverse as water treatment and downhole oil drilling.

Clearance for such applications (and marketing claims) relies on a battery of toxicity and efficacy tests, mandated by federal, state, and local governmental bodies. These tests take time, and their cost can be significant—certainly much higher than many of the 2000 commercial formulators can afford to pay on their own. Because governments are asking for more and more data, these tests will become ever more costly in the future.

Some signs are surfacing, though, that chemical suppliers may be starting to rethink this situation. If some of them decide to discontinue offering service, this would be a fundamental change for the industry, and would affect both suppliers and formulators. Early indications are that the changes would begin occurring first in the quaternary ammonium surfactants business. However, if they were to happen there, where they would have the most impact, such a move could easily spread to other areas of the commercial detergent business.

Basically, the problem affecting the quaternary ammonium surfactants industry has been an influx of producers over the past few years into what is a rather small business. It used to be dominated by two companies, Onyx and Lonza. But other companies have expanded their operations or jumped into the business. Huntington Laboratories, which used to be solely a formulator, now also sells quaternary ammonium surfactants on the merchant market. Likewise, Jordan Chemical, Emery, Henkel, Hexcel, McIntyre, Rohm & Haas, Scher Chemicals, Hilton Davis, Sherex, Akzo Chemie, and Mason Chemical also have entered the business. And PPG Industries' new family of surfactants will include a line of quaternary ammonium surfactants, both for regular surfactant applications and for biocides. The result is that prices have taken a nosedive, causing low margins and low returns.

Typical for a well-established market with a significant influx of producers, much of the competition has focused on prices—low prices for "commodity" quaternary ammonium surfactants and little service. Companies that still rely heavily on service to sell their products are finding that more and more a disadvantage. Service always has been an expense to be absorbed, but as quaternary ammonium surfactant prices have fallen, the margin into which those expenses could be absorbed has grown smaller and smaller. That is one reason why, as one supplier notes, "The money is being made by the formulator, not the supplier."

"Customers are willing to put you over a barrel to match the prices of the guy who isn't offering any service," grumbles one quaternary ammonium surfactant supplier. The result is that suppliers are taking a hard look at the service they provide. They are considering two basic options: turning away from their traditional service orientation completely or offering it strictly on a pay-as-you-go basis. "We all used to be very service oriented, but that has changed," says the supplier. "Now it comes down to the question: How much are we going to continue to do?"

the on-premise laundry, which tends to be a small operation, is shrinking in market share, whereas the market share held by the large individual laundries is growing, frequently by concentrating small outlets. The market for commercial dishwashing is growing, too, as the restaurant business expands.

On the other hand, the market for hard-surface cleaners, at least for the time, is stagnant, primarily because the public sector, an important component of the business, has cut budgets. Such budget cuts haven't frozen all industrial and institutional spending, however. The hospital hygiene market, for example, is growing "tremendously," according to one enthusiastic marketer.

On the industrial side, one of the major end-use applications is in metalworking, and in this, the automotive industry is most important. Commercial cleaners remove oils, greases, and dirt that are found on delivered metal. Their use is especially important before precoating preparations such as phosphating, anodizing, and galvanizing are done, and before enamels, coil coating, or other coatings are applied. Commercial products also are used to clean metal products prior to shipping, and for general-purpose cleaning of vehicles.

Sometimes companies selling these kinds of cleaners can find ways to integrate their product lines. For example, in the metalworking cutting fluids market, Henkel recently began a program of vertical integration. Its theory is that because it sells cleaners to remove metalworking fluids, it can better control the system if it sells the cutting fluids, too.

Markets in different geographical areas are growing at different rates. Some countries and products still show double-digit growth, although those examples admittedly tend to be infrequent. Developing markets continue to offer opportu-

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nity. For example, Nigeria has built 20 to 30 new breweries in the past five years. The potential for bottle cleaning agents there has grown 100% per year—to the point that the market just for bottle cleaners is now 12,000 metric tons per year.

Marketers cite India's auto making as a similar case. Within the next five years, India will have five auto manufacturing lines, so it will be a major market for metal-cleaning products.

Even developed countries can still offer growth in selected market sectors. For example, over a 10-year period, the aluminum container market in the U.S. increased tremendously to the point of virtually replacing steel for beverage cans. Firms that sold surface-preparation cleaners for aluminum grew dizzy from the fast-paced growth.

More commonly, however, growth does not exceed the increase in GNP. That helps explain the pressures on companies in the commercial detergents business to find new product lines, new market areas—niches where markets are growing.

One factor that formulators for this business will be counting on in their search for new markets or new products will be raw materials, particularly surfactants. At present, in the household detergent industry, anionic and nonionic surfactants roughly share the market. For the commercial business, however, nonionics dominate, accounting for nearly two thirds of the surfactants consumed in the industry.

The major nonionic family for these commercial uses is the ethoxylates, which serve as the industry's workhorses. Nonelectrolytic, they function as good wetting agents, detergents, emulsifiers, and dispersants in a host of formulations—and at an attractive price.

The most widely used surfactant is alkylphenol ethoxylate, followed by alcohol ethoxylate. The market is relatively stable, suppliers report, with growth tracking that of GNP, and has shown no dramatic changes. In particular, because there are a host of suppliers for alkylphenol ethoxylate, the supply of this compound is greater than the demand. Therefore, customers benefit from price competition—or price deteri-

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oration, according to one supplier. Linear alkylbenzene sulfonate, the workhorse of the household soap and detergent industry, is the third largest surfactant for commercial formulations, but the amount of it sold for commercial uses is overwhelmed vastly by the volume consumed by household detergents. It is no wonder that producers pay most of their attention to the household market.

Alkylphenol ethoxylates, however, are under a cloud because of sluggish biodegradability. The major marketers in the household detergent industry, for example, have a voluntary agreement to not use these compounds in their products because of concerns on this score. Some major commercial-product makers, such as Henkel, have abstained voluntarily from using alkylphenol ethoxylates for institutional cleansers and intend to withdraw their use from industrial compounds as soon as they have developed suitable substitutes. However, most companies in the economically squeezed commercial business depend on them.

How much of a problem this is has been debated extensively, but some suppliers don't yet believe the question has been resolved. Says one: "I'd like to go back and reargue the biodegradability question, with comparsion to alcohol ethoxylates [often recommended, because of better biodegradability]. There is a 10 to 15 cent-per-lb premium for those materials because there is some evidence, maybe, that they biodegrade quicker. I don't think you need to pay that kind of premium. The evidence argues that materially there isn't that much difference in the rate; it is in percentage points, not factors of 10."

Industry observers note that, at present, no move is under way to remove alkylphenol ethoxylates from commercial products. The market for such products is much smaller, of course, than the household one, so presents much less of a cumulative problem. And because the number of even halfway large companies is so small, there are no visible targets of consumerist wrath, as the larger companies in the household detergent industry could be.

Nonetheless, notes Houston's McLaughlin, "Concern over the biodegradability and toxicity of alkylphenol ethoxylate residues will definitely lead to new product introductions in some applications."

Low-foaming characteristics, always important in the commercial business, will become even more important as these markets increasingly mirror the same trends occurring in the household soap and detergent industry—lower washing temperatures for energy and cost savings. Also, greater mechanization of systems means more of a demand for lowered foam. For commercial dishwashing, formulations need to be increasingly resistant to foam formation, as the processing times shorten.

BASF Chemicals, Rohm & Haas, GAF, and Olin are the major suppliers of low-foam surfactants for this business. Low-foamers include block copolymers and the alkoxylated straight-chain alcohols, which are good wetting agents that don't generate foam. BASF, for example, has built up its strengths in low-foam, block copolymer surfactants—ethylene oxide/propylene oxide blocks—sold primarily to formulators of dishwashing and rinse-aid products.

By 1987, PPG also will have joined the roster of suppliers of low-foam surfactants when it brings out the third line in a new family of surfactants. PPG marketers say the materials will be "something structurally similar to the ethylene oxide/propylene oxide block copolymers, but quite different—with lower foam and better detergency."

Other suppliers report a small but growing interest in short-chain nonionics, which are being used only infrequently at present in commercial formulations, and in new polymer builders for commercial formulated detergents.

BASF Chemicals, for example, has begun importing from its parent in Ludwigshafen acrylic-acid polymers as alternative builders. The polymers act as chelating agents and dispersants. In Europe, they are already incorporated into some household detergents in phosphate-restricted areas. The company believes that the conditions under which commercial laundries in the U.S.

operate are similar to conditions for household laundries in Europe. Therefore, it decided that the polymers would be of interest to the commercial detergent business in the U.S. The polymers can tolerate higher temperatures, higher soil loadings, and a more concentrated washing system, BASF says. Its present marketing emphasis is the commercial laundry area, but at some point the polymers will be of interest for hard-surface cleaners, company marketers predict.

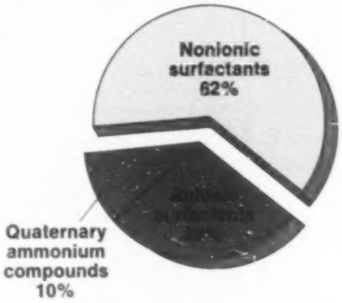
Temperature is a constant concern for customers, so formulators must be aware at all times of trends regarding this parameter—such as the economic pressures toward lowered temperatures. These, and more mechanization, are in turn driving the industry to products formulated as liquids. Liquids are easier to measure and dispense and have higher solubility. However, they are also a much more frustrating technological challenge, say Henkel researchers.

Customers who use liquids can automate a process more easily, with better meter and process control. All it takes is a little pump to meter the liquid into water. Dosing of powders can sometimes be complicated. Certain chemicals are hygroscopic, causing maintenance and sticking problems. Customers generally don't like to do any maintenance—and often, they haven't the technical expertise to do it.

However, "from a product technology standpoint, we can work more-sophisticated chemicals into powders," says one Henkel researcher. "With liquids, only about 50% is 'active,' and the rest is water."

Debates have persisted on the desirability of powder detergents vs. liquids—for example, shipping costs and packaging are different. Marketers say they are becoming increasingly concerned by the problem of having to get rid of the containers for liquids. Liquids require probably three or four times as many containers as solids, and they are bulky containers to boot, compared with the paper or laminate bags powders are sold in. The question of costs also must be addressed: Marketers don't accept containers back from customers for reuse, because of safety. But they agree that bottles will be a problem in the future when marketers may be forced to develop re-use applications, or reconditioning technology, or perhaps mobile shredding units—customers will demand it. These concerns will slow the move to liquids, several marketers predict, until the ease of automatic dosing carries the day.

Nonionics dominate North American surfactant use



1985 Total commercial surfactant market = 400 million lb

Sources: Industry, C&EN estimates

If commercial products are manufactured more as liquids, that will be a major difference between that business and the household-products industry, which—at least in the laundry-detergent side of it—has refused to produce a majority of its products as liquids. But that would be one of the lesser differences between these two surfactant markets.

To commercial product marketers, the major difference between household and commercial products is that their companies are formulating and selling chemical systems designed to tackle completely different conditions. For example, in the commercial laundry business, "textiles get really dirty, and there are all kinds of fabrics done in one go," says one product-development specialist. "Household detergents don't have to face the same degree of dirt, and the housewife separates her laundry into batches." Moreover, whereas a home washing machine might have a one-half-hour cycle, a commercial machine would process a load in 15 minutes.

Similarly, a home dishwasher normally might take about one-half hour. In the big institutional dishwashers, it takes 20 to 40 seconds for plates to go through the tanks. The actual transit time might be two or three minutes, and of that, the contact time with the tanks is only 20 to 40 seconds. Hence, formulations rely on much stronger chemicals and a pH frequently higher than 13. Sodium hydroxide is a major component of commercial dishwashing cleaners, which would never be used in household formulations, if only for safety reasons.

In some phosphate-restricted areas, legislation makes a distinction between household and industrial cleaners, so that phosphate still can be used as a builder in industrial cleaners. In a number of European countries, commercial product compounds have escaped regulations governing the biodegradability of antifoaming agents. But that situation is changing. For example, in West Germany this year, biodegradable antifoaming agents must be used for bottle washing and breweries. That has resulted in a switch from ethoxylated fatty alcohols to the corresponding ether derivatives. And West German law extends that mandate to all commercial market sectors by 1989. Other countries, including Switzerland and Italy, already have phosphate bans for laundry detergents, even commercial products. Austria is expected to follow suit soon.

Government agencies that regulate the environment have long been monitoring or controlling the wastes from commercial car washing. For example, the biodegradability and solvent accumulation, particularly from motor cleaning, have been measured. But in true "every problem is an opportunity" spirit, Henkel developed a formulation that, when concentrated, spontaneously emulsifies oils and solvents, but when diluted to one tenth, the emulsion breaks and the oil separates out. Dubbed P3-grato 12, it contains a nonionic surfactant, organic builder, corrosion inhibitor, and coupling solvent—but no phosphate, solvents, mineral oil, or emulsifiers. It has been approved—indeed, is required—for use at Frankfurt Airport on parking areas, for courtesy cars, and for motor cleaning to reduce the amount of oil in effluent washwater. ☐

PRELIMINARY PROGRAM
ACS meeting in New York City
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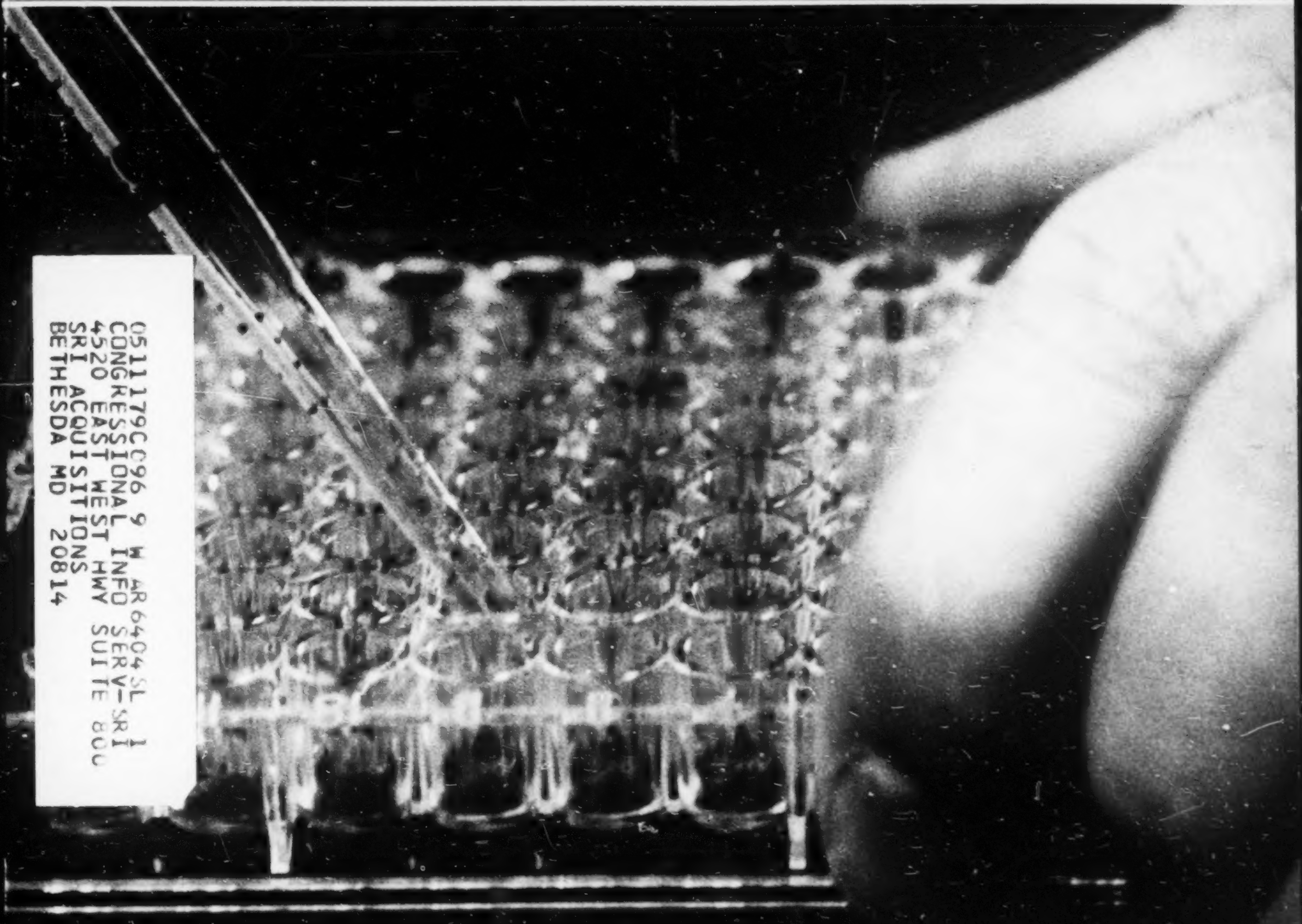

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Synthetic Antiviral Agents

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- **Tissue culture techniques developed for cloning guayule could lead to commercial use of the rubber-yielding plant.** **Page 5**
- **U.S. Synthetic Fuels Corp. goes out with a bang—a final controversial commitment.** **Page 5**
- **EPA proposes immediate ban on five asbestos uses and complete phaseout of the fire retardant in 10 years' time.** **Page 6**
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Cover: Cells growing in culture media will be infected with viruses in testing antiviral agents

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Business

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Control of scientific research seen as growing, according to study by Congress' Office of Technology Assessment. **Page 17**

Quantification of hazardous waste generation difficult, as two new reports on chemical industry's handling of waste demonstrate. **Page 18**

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New nonsulfurous pulping process for papermaking is based on the use of acetic acid and ethyl acetate. **Page 25**

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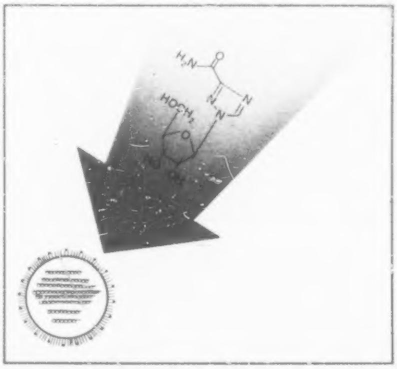

Special Report

Expanding array of synthetic compounds now are being tested clinically to determine efficacy in treating many viral infections, including AIDS. **Page 28**

LIABILITY AWARD SYSTEM: Survey shows many favor changes

A new group was formed earlier this month in Washington, D.C.—the American Tort Reform Association. According to the organization's president, James K. Coyne, its aim is to eliminate "a disease that consumes as much as $50 billion of the U.S. gross national product and wastes some of America's finest minds, best products, most successful research and production facilities, and saps the creativity and energy of public and private enterprises."

The disease Coyne refers to isn't physical. It is the epidemic of lawsuits, some 16 million per year according to ATRA, filed under the tort liability system. Torts are wrongful actions that the law requires the victims be compensated for. However, Coyne, who is also executive vice president of the American Consulting Engineers Council and a former Congressman from Pennsylvania, contends that the current system has led to liability awards that show no relationship to fact, fault, or fairness.

That ATRA isn't alone in its concern is obvious from a recent survey of risk managers at 1300 U.S. companies. That survey shows "a strong referendum for change," says David Holbrook, director of the study and executive vice president of Marsh & McLennon Inc., the insurance brokerage firm that produced the study.

Begun at the end of 1984, the survey included risk managers from a broad spectrum of U.S. corporations, including manufacturing and chemical firms, educational institutions, health care providers, and retailers. The survey found broad dissatisfaction with several aspects of the present tort law system. For instance, 75% of respondents agreed the current jury system under trial conditions cannot reasonably resolve complicated scientific questions of causality. And 63% favored reforming the tort law system through uniform federal standards.

The area of tort law receiving the strongest reactions from risk managers was that of punitive damages—awards assessed to punish antisocial, but not blatantly criminal, acts. Here 90% of respondents agreed that legislation should be considered that would prevent or discourage plaintiffs' attorneys from seeking punitive damages without valid purpose. To discourage abuse of the system, 79% would prohibit plaintiffs' attorneys from obtaining fees for the punitive damage portions of claims.

The survey found opinion divided on other appropriate ways to reform the tort legal system. By a 50 to 44% margin, the risk managers favored federal legislation to define

Although chemical companies surveyed are more concerned about their own liability . . .

Survey question	Response of chemical and pharmaceutical firms	Response of all industries
Products liability reform very or somewhat important to company	87%	65%
Very or somewhat exposed to loss of sales due to product recall	56	32
Use environmentally hazardous substances	94	69
Very or somewhat concerned about occupational liability issues	97	84
. . . they see the same problems with the present tort law system . . .		
Agree that current system may be abused but generally works well	24	29
Agree that current jury system cannot reasonably resolve scientific questions of causality	80	75
Agree that the tort system is the most efficient way to protect the environment	52	52
Agree that excise tax is necessary to fund designated-site cleanups	58	58
. . . and favor the same measures that other companies do to reform tort law		
Agree that federal tort reform legislation establishing uniform standards is the most effective way to reform present system	65	63
Agree that legislation to provide specific solutions should be investigated	44	39
Agree that no-fault insurance is the best way to deal with diseases that arise many years after exposure to specific products	57	62
Agree plaintiffs' attorneys should be prohibited from obtaining fees for punitive damages portion of claims	73	79

Source: Marsh & McLennan survey

the legal responsibility of insurers for occupational diseases, but only 35% supported (and 58% opposed) legislation to create a special fund for compensation similar to that for black-lung disease. A no-fault recovery system—such as that proposed by the American Bar Association, that would aid deserving victims of environmental impairment who might not ordinarily seek compensation because of high legal costs—was favored by 59% of respondents. However, by a 55 to 34% margin, they rejected the idea of an excise tax to fund such a system.

"The risk managers appear to be saying that we can bite the bullet now—and go through the arduous, but necessary, task of reforming tort law—or we can simply wait and face the consequences of inaction," Holbrook says. Among those consequences are increased wariness to take even the prudent risks that are essential for growth, diminished competitiveness of U.S. businesses in world markets, and further deterioration of insurance markets.

ATRA says it will work at both the federal and state levels to address some of these concerns such as reforming lawyers' contingency fees; limiting awards for punitive damages and noneconomic losses; restricting the use of joint and several liability; and imposing appropriate statutes of limitations.

ATRA has 24 founding member organizations—including such diverse groups as the American Association of Community & Junior Colleges, the National Paint & Coatings Association, and the National Association for Child Care Management—which together represent 960,000 businesses, professionals, and public entities. Coyne expects that eventually ATRA will have 200 member organizations.

Less than a week after ATRA was formed, Coyne testified before the Public Works & Transportation Subcommittee on Investigations & Oversight, chaired by Rep. James L. Oberstar (D.-Minn.), which is holding hearings on the liability insurance crisis. In addition, Coyne says, ATRA has been invited to the White House next month to express its concerns and explore ways of achieving its goals. □

Guayule cloning could give high-yielding plant

Tissue culture techniques for cloning guayule have been developed successfully by scientists at the University of California, Irvine. That cloning technology could give plant breeders a new tool for developing high-yielding varieties of the rubber-producing plant. And such varieties, in turn, hold promise for promoting commercial use of guayule.

Guayule has been of interest for some years as a potential new, domestic source of natural rubber. The plant grows in the desert climate of southwest Texas and northern Mexico, and it produces natural rubber that is nearly identical to that from tropical rubber trees. But a major obstacle to speeding commercial development is the need for higher-yielding varieties.

Conventional plant breeding techniques don't work with guayule, explains David N. Radin, a plant cell geneticist at Irvine who developed the cloning technology with funding from the National Science Foundation. Guayule, he points out, is a highly heterozygous plant, an outcrossing species. It is very difficult to breed true varieties. But with the tissue culture technology, breeders could reproduce large numbers of genetically identical offspring from an individual improved guayule plant.

"One such plant," Radin says, "could produce enough clones to allow field testing of the new selection on a large scale under conditions similar to those expected during agricultural production. If these preliminary tests proved successful, clonal reproduction then could be scaled up to provide the improved seed needed for crop production."

For cloning to be useful in this way for guayule, Radin aimed his research specifically at developing techniques that could be used with tissue from older plants. Important traits such as drought resistance and rubber yield, he explains, often aren't expressed until plants are mature.

In cloning, small pieces of living plants are used to start the growth tissue from intact mature guayule of tissue cultures in vitro. Once established, the cultures produce undifferentiated tissue that can be transferred to another culture medium that induces root growth. The plantlets then can be removed and grown in soil the same as normal seedlings. □

Synfuels Corp. closing with one last action

U.S. Synthetic Fuels Corp. has taken its last official action and is preparing to close up shop. But the once-touted agency that was designed to help make the U.S. independent of foreign oil is not going quietly.

At its final board of directors meeting, SFC approved an amendment agreement for Union Oil's Parachute Creek oil shale project that provides it with $300 million in loan guarantees and up to $173 million in price guarantees. That project already has received about $800 million worth of awards from the agency. SFC believes it was legally obligated to make this commitment despite a December order from Congress that it was not to make any further awards. Edward E. Noble, SFC chairman, says the corporation made its commitment to Union Oil in October last year

Noble: ready for the next crunch

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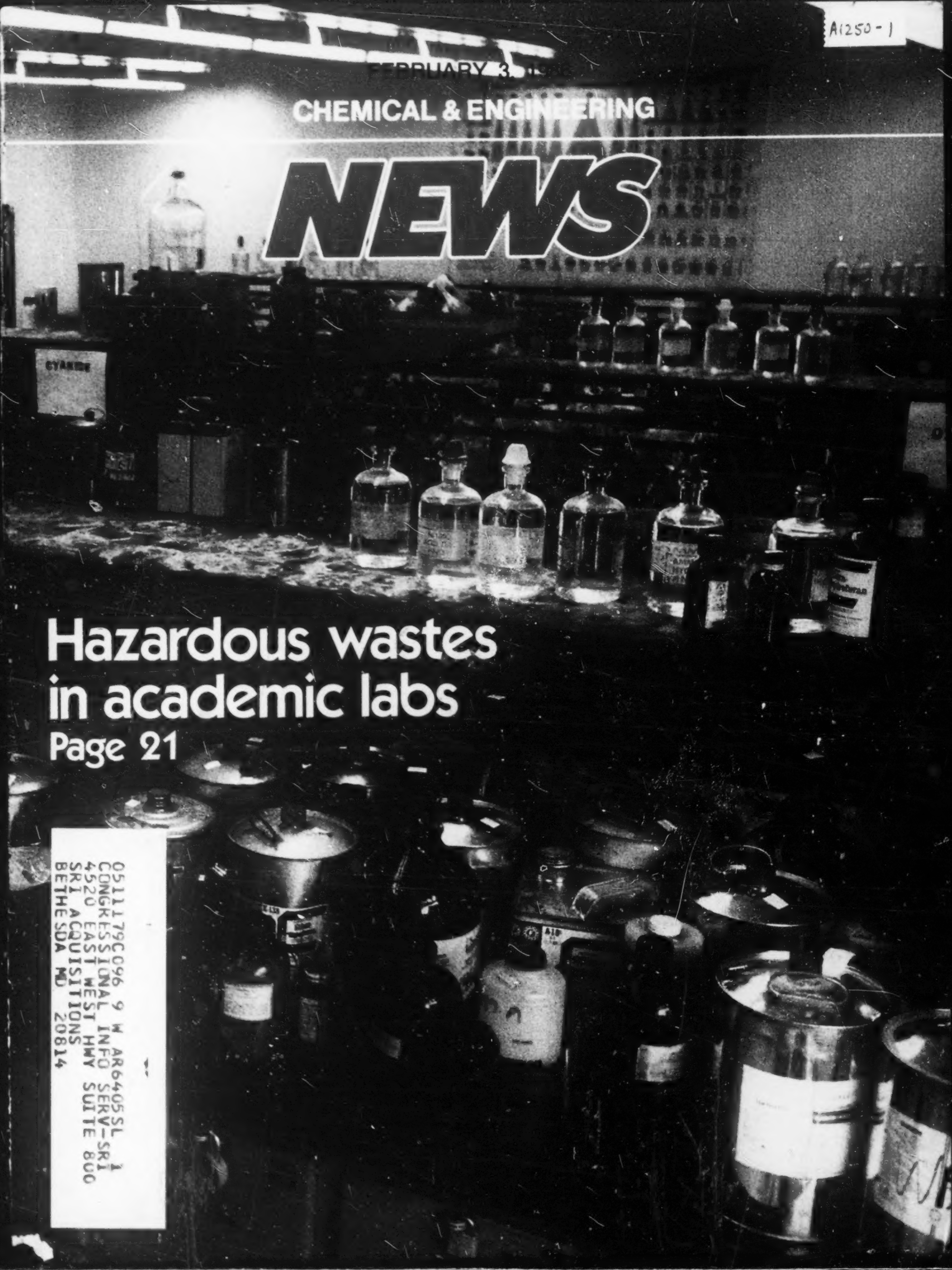

Hazardous wastes in academic labs

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- ***Challenger*'s external liquid fuel tank or its solid fuel booster rockets may have been the source of the explosion.** Page 5
- **Future scientific experiments planned for the space shuttle put on hold.** Page 6
- **Goodrich and Uniroyal will merge their tire businesses in a 50-50 joint venture.** Page 6

Cover: Waste chemicals from major cleanup of several labs at the University of Maryland, collected by the school's department of environmental safety

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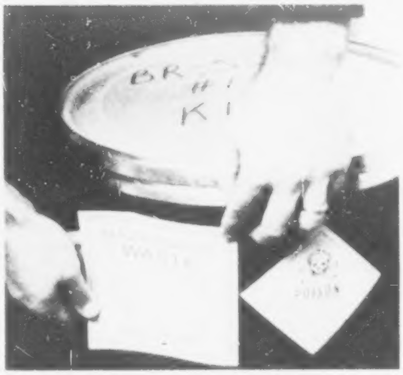


Special Report

Colleges and universities are making efforts to dispose of hazardous wastes safely to comply with tougher federal regulations. Page 21

Work-Force Reduction Programs Create New Employment Picture

Five years of job cuts leave employees feeling insecure; leaner chemical firms save on payroll costs but may risk losing employees' loyalty

David Webber, C&EN Washington

Du Pont made headlines last year with an early retirement incentive plan so seductive that some 11,200 salaried employees—nearly twice as many as expected—took the money and ran. The heavy acceptance rate left the company thin on key personnel in many areas. But while critics carped, Du Pont coped, and now, having taken less than a year to catch its breath, the firm is ready to begin laying off another 1000 to 2000 salaried workers.

The company's quick return to a job-slashing guise is just one more indication that the chemical industry's attack on payroll costs—especially white-collar salaries and benefits—is probably still a long way from having run its course. There were some 13,000 fewer salaried employees, including chemists and chemical engineers, working in the chemical industry at the end of 1985 than there were a year earlier. But even that large figure masks the true extent of job dislocation in white-collar ranks, since companies were still hiring new salaried personnel last year. In the 13 biggest chemical firms alone, probably close to 20,000 salaried employees left their positions last year as the result of either layoffs or the acceptance of early retirement inducements.

Du Pont's plan to lay off another batch of employees over the next two years is not the only future job cut on which chemical employees can count. Dow Chemical launched programs in November aimed at trimming 2500 people from its glob-

Staffs pruned throughout chemical industry in 1985

Some companies just trimmed while others hacked away whole branches, but almost every one of the biggest employers in the chemical industry pruned its workforce in 1985. In some cases, companies offered early retirement incentive plans (ERIPs) that lured thousands of employees from all departments off the payroll. In others, limited special early retirement programs or layoffs cut staffs more selectively.

Whatever the means or reasons, the staff cuts were enough to reduce overall employment in the chemicals and allied products sector by 20,000 workers during the year, according to seasonally adjusted Labor Department statistics. A C&EN survey of a group of 13 major chemical producers, which together accounted for some 57% of chemical industry employment in 1984, shows that composite employment remained essentially unchanged in 1985, despite a number of major acquisitions.

Last year's assault on payroll was the latest surge in a battle against overhead that began, as far as personnel is concerned, after employment reached its most luxuriant growth around 1979. Between the end of that year and December 1985, total chemical employment dropped some 80,000 people, more than 7%. The size of the decrease, however, was limited by job increases in the drug and paint segments. Large work-force reductions were made in the agricultural chemicals, plastics and synthetics, and inorganic chemicals segments especially. Between the end of 1980 and the end of 1985, composite employment by the group of 13 chemical companies with the biggest payrolls fell about 84,000, or 13%.

Following are selected company-by-company reports on the employment reduction actions from C&EN's survey of the group:

American Cyanamid: The firm will lay off 400 salaried and hourly workers at its Linden, N.J., facility this year.

Dow Chemical: The company reported no layoffs in 1985, but in November offered salaried U.S. employees an ERIP that expired last week. The move, part of a $475 million restructuring of the company (C&EN, Nov. 25, 1985, page 6), is designed to lead to a worldwide employment decrease of some 2500 people. Dow's payroll grew in 1985, primarily the result of the Jan. 1, 1985, absorption of the Texize division of Morton Thiokol.

Du Pont: Companywide early retirement inducements last year lured about 11,200 salaried employees off the payroll. Another 1000 to 2000 salaried employees will be laid off over the next two years.

Ethyl Corp.: In the company's only special early retirement offer, about 150 employees at the Baton Rouge facility left. There were no layoffs.

W. R. Grace: The firm had no layoffs in 1985 and just one ERIP, a fourth-quarter offer to fewer than 150 employees of the catalyst-producing Davison division. Overall employment increased through restaurant acquisitions.

Hercules: The principal reason for the al payroll by the end of last month. Monsanto, having reduced its work force substantially last year through layoffs and retirement incentives, still has several hundred staff members who will be laid off on March 31 or when they find a new job, whichever comes first. And Union Carbide, having hacked away thousands of jobs last year through incentives and layoffs, is widely expected to pursue another round of salaried staff cuts once the company, currently in the process of selling off some major assets, assumes its new size and shape.

The assault on the white-collar work force has been and continues to be widespread. Just last year, almost all of the 13 chemical companies with the largest employment rolls implemented reductions in force—as current personnel jargon calls them—in the form of either layoffs or special early retirement offers.

At Lamalie Associates, a New York City-based executive search firm, the number of chemical industry executives newly entered in the firm's database of people looking for jobs jumped from 96 in 1983 to 158 in 1984 to 340 in 1985. And as a sign of lowered expectations all around for future employability of professionals in the chemical industry, early predictions from academia indicate that the class of 1988 will include 5% to 10%—or even a greater percentage—fewer chemists and chemical engineers than did the class of 1985.

"That's quite a rapid response to the lessening demand for chemists and chemical engineers," remarks Thomas V. McCarthy, vice president of human resources at Hercules.

Analysts typically praise sharp reductions in force because they help companies both lower their break-even points and reposition their employees in higher growth areas. As such, job cuts are considered by chemical industry analysts an appropriate response to a changed business—one characterized by slow growth in traditional markets, the need to develop new value-added products, and heightened international competition. Even employees included in work-force reductions sometimes concede—if adequately mollified by a good severance package—that the action makes good business sense.

Nevertheless, observers have begun to wonder what costs might be hidden by the more evident gains of the job-cut spree. About the only truly measurable effect of large-scale work-force decreases is the reduction of payroll and related costs. The question of the morale of those who survive a job cut remains a great imponderable. Pessimists assert that the spared, fearing another round of cuts that they will fail to escape, lose spirit. Optimists claim the survivors develop a sense of belonging to the cream of the work force, and that morale rises as a result.

On the negative side, the most obvious disadvantage of large-scale job cuts is the loss of experienced personnel. "The loss of experience constitutes a disruption to the continuity of know-how in the organization," says Hercules' McCarthy.

McCarthy also points out that

decline in Hercules' work force was the sale of its explosives business. About 100 people retired in an ERIP offered in March to some 900 salaried employees.

Monsanto: Excluding the 10,970 Searle employees (June total) added to the payroll in October, Monsanto's total work force shrank nearly 5500 last year, about half through ERIPs and the rest through layoffs and attrition. Several hundred more Monsanto staff members will be laid off by March 31, and 400 to 500 Searle employees are slated to lose their jobs this year.

Olin Corp.: As part of a restructuring announced in September (C&EN, Oct. 7, 1985, page 4), the company is more than halfway through a program intended to cut 4200 people from its payroll in selected areas. Of that total, however, 3500 are attached to operations that Olin has sold or intends to sell. About 700 salaried employees with "support roles" related to those operations, a spokesman says, are in the process of being laid off. There was no ERIP. In November, Olin took over for the federal government operation of the Lake City Army Ammunition plant in Independence, Mo. That added about 3000 workers to company rolls. Factoring out that addition, Olin's work force shrank about 21% last year.

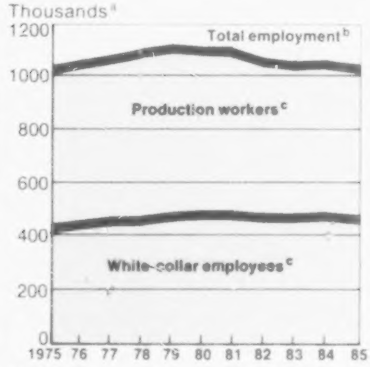
PPG Industries: The company quietly laid off at least 352 employees last year (168 of them salaried) in several actions (C&EN, Dec. 9, 1985, page 6).

Union Carbide: About 7800 U.S. and Puerto Rican employees left the company, and perhaps more than 3000 overseas employees did, too. The company, having scheduled a slew of asset sales in 1986, will be a much smaller enterprise by midyear. Analysts expect another round of staff reductions once the current consolidation is completed.

	Total employment[a]			% change		Cut staff in 1985 by	
Company	1985[b]	1984	1980	1984–85	1980–85	Layoffs	ERIP[c]
Air Products[d]	18,700	17,700	15,800	6%	18%		
American Cyanamid	38,762	38,157	42,600	2	−9	X	
Celanese	19,000	21,500	36,500	−12	−48		X
Dow Chemical	53,303	49,800	56,800	7	−6		X
Du Pont[e]	117,000	124,893	136,259	−6	−14		X
Ethyl	10,574	11,081	15,000	−5	−30		X
W. R. Grace	90,000	80,000	91,700	13	−2		X
Hercules	25,448	26,262	22,900	−3	11		X
Monsanto	56,112	50,754	61,800	11	−9	X	X
Olin	17,000	17,800	21,000	−4	−19	X	
PPG Industries[f]	37,500	37,700	37,300	−1	1	X	
Rohm & Haas	11,898	11,911	13,200	0	−10		
Union Carbide[g]	87,500	98,366	116,100	−11	−25		X
TOTAL	**582,797**	**585,924**	**666,959**	−1%	−13%		

a As of year's end unless noted otherwise. b Preliminary figures. c Early retirement incentive program. d As of end of each fiscal year (Sept. 30). e Excludes Conoco. f Annual averages. g Estimate.

Salaried workers not spared as chemical employment fell



a Seasonally adjusted for December of each year unless noted otherwise. **b** Chemicals and allied products employment. **c** Latest available 1985 figure is for November. **Source:** Labor Department

though job cuts can be seen, in the positive viewpoint, as ways to open career avenues for younger employees, the reductions also mean that there are fewer positions that can be used to develop high-potential executives.

Also, points out Salomon Brothers analyst Leslie Ravitz, excessive cuts can potentially hamper a company's efforts to develop new products. "If you pull people out of R&D and technical service, you could miss opportunities," he says.

Employment experts also note that even after a reduction in force is completed, firms can remain at risk in terms of adequate staffing and experience. "Many companies have taken away as much fat as they can," comments John F. Johnson, president of Lamalie Associates. "There are fewer backups for key jobs. Companies have to recognize that, in many cases, if something happens to an individual in a critical role, they may have to go outside the company."

Perhaps the most imponderable aspect of the most recent spate of work-force reductions is their impact on employee loyalty. The concept of employee loyalty itself evades definition, but it does seem to have more than average relevance to the chemical industry, which traditionally has been considered a highly paternalistic business in which one-company careers are the norm rather than the exception.

The chemical industry's professionals have had their feelings of security shaken before—in the early 1970s, in 1975, and earlier in this decade. But all those employment cutbacks coincided with economic recessions. Last year's broad assault on the salaried work force came during a period of economic growth, albeit slowing.

"The loyalty question is coming up more often," says McCarthy of Hercules. "When you're 25 to 30 years old, and this guy who spent 30 years with the company ends up losing his job or being strongly encouraged to retire at 55, you say, 'How much security do I have?' "

Audrey Freedman, executive director of the Conference Board's human resources program, remarks: "It used to be that if you offered loyalty and support and, to some extent, ceded your good judgment to the company, the company would take care of you. That kind of exchange is not thinkable any longer for most companies, even those that are not restructuring."

Hercules' McCarthy asserts that this general comment does not apply entirely to chemical employees. "I still think the mentality in the chemical industry is that you join a company off the campus and that, more than likely, that company will be your career-long employer," he says. He acknowledges, however, that this attitude is not indestructible. "The reductions in force could tear that fabric, but it will be years before we find out."

McCarthy: continuity of know-how

Lamalie's Johnson is less equivocating. "The day of the one-company career is without question over," he declares.

Not that corporate leanness is the only reason for that. Observers also note the more independent attitude of younger employees toward their employers. "Companies will never have the same kind of loyalty in their executive work forces as in the 1950s," Johnson says. "The value system of the worker in his thirties has changed." If anything, the two trends—less corporate paternalism and greater employee independence—have coincided and, in doing so, have been mutually reinforcing.

Furthermore, from the management point of view, disruption of the old system of assumptions tied to employee loyalty can be beneficial. "One problem with managers full of loyalty is that you get a great suspension of critical thinking," points out the Conference Board's Freedman. "The watchword becomes, 'Find a mentor and brownnose him to death.' That produces a roomful of so-called managers who do nothing but ratify each other's judgments."

Nonetheless, chemical firms realize they must maintain and, in light of this decade's job dislocations, revitalize morale. At Hercules, for example, management is meeting more frequently with employees to listen to their job concerns. "I think we are becoming more enlightened about how valuable the feelings of our employees can be if they are positive," McCarthy says.

Says Lamalie's Johnson: "It will be incumbent on the employer to instill a level of confidence that there will be opportunities for people in the company."

And Freedman, in comments on the Conference Board's 1986 labor outlook report published late last year, believes that the ultimate impact of the past few years' work-force cuts is not yet apparent. "Today young managers and older ones can assume nothing about the reliability of regular career advancement. Traditional corporate cultures of security, especially for salaried workers, are shattered." □

WATER
REACTIVE
2117

Hazardous Wastes In Academic Labs

Howard J. Sanders, C&EN Washington

Rising on the campus of Stanford University, in a picturesque meadow near the university's historic bright-red equestrian stables, is an unusual facility for treating and disposing of hazardous chemical and biological wastes. The $7 million installation, which is expected to begin operating in September, will consist of three adjacent buildings.

One building will contain facilities for handling infectious biological wastes (mainly from the university's hospital) and chemical wastes, as well as an incinerator and a laboratory. Another building will house several laboratories and a facility for handling low-level radioactive wastes. The third building will contain administrative offices and a center for the safety training of students and professionals. The complex probably will be the largest, most modern, and most well-coordinated installation of its kind on any campus in the U.S.

Alain DeCleve, director of Stanford's department of health and safety, comments, "The new centralized installation, which will replace facilities scattered throughout the campus, should increase substantially the safety and efficiency of our hazardous waste management program. We are especially pleased that the new facility will include separate handling areas for different types of waste materials, an environmentally sound high-temperature incinerator, a fail-safe system for spill control, and stringent safeguards in the event of a fire or earthquake."

The Stanford facility is a striking example of efforts now under way at colleges and universities to improve their disposal of hazardous wastes. One reason for this growing activity is the increasing regulation of hazardous waste disposal by the federal government and the states. The Resource Conservation & Recovery Act (RCRA), whose regulations took effect in 1980, initially applied fully only to installations that generated 1000 kg or more of hazardous waste per month. After March 31, however, the law will apply to an increased extent (but not fully) to generators that produce more than 100 kg but less than 1000 kg per month of such wastes. According to one estimate, this change will raise the number of schools under more-than-nominal RCRA regulation by about 1500.

Academic institutions also must comply with the federal Comprehensive Environmental Response, Compensation & Liability Act (commonly known as Superfund), passed in 1980. Under this law, organizations that have disposed of hazardous waste improperly in waste dumps are required to clean them up, which can be expensive. Although this law has applied mainly to companies, the University of Minnesota and North Carolina State University have been placed on Superfund's National Priorities List for cleanup of specific disposal sites they used in the past.

Industrial hygienist examines containers of waste materials gathered from a university chemistry lab

Colleges and universities also are becoming increasingly aware that, even if they turn their hazardous waste over to a commercial disposal firm, they are still liable for any health or environmental damage the stored waste might eventually inflict. This, in turn, is causing schools to be extremely cautious in selecting a disposal firm to handle their hazardous wastes.

As part of their expanding waste management programs, many schools are recovering useful materials from hazardous wastes and, at the same time, reducing the volume of such wastes that must be disposed of. In part, this is cutting down the cost of waste disposal, which is becoming more and more expensive.

Russell W. Phifer, special services market manager at Resource Technology Services in Devon, Pa., estimates that in recent years the cost of off-site hazardous waste disposal has been increasing at a rate of at least 10% a year. The cost of organic laboratory chemicals, he believes, has been growing at least 5 to 10% a year.

Many schools, and especially chemistry departments, also recognize that training in the disposal of hazardous wastes is an essential part of a chemistry student's education. Ralph O. Allen, a chemistry professor at the University of Virginia, says, "We can seize upon this opportunity to teach our students more about safety, chemistry, and good citizenship."

In years past, many academic laboratories (as well as industrial laboratories) did very poor jobs of hazardous waste disposal. University students and their professors frequently poured waste chemicals down the drain or threw them into garbage bins. Professors, their assistants, or custodial people might just pour the chemicals on the ground in some isolated spot or in a quarry or a waterway. At many schools, some of these practices still go on.

Mercuric Sulfate
A bottle of waste mercuric sulfate is added to other discarded chemicals placed in a lab pack

Another problem at colleges and universities has been the tendency of many professors to store sizable amounts of chemicals on lab shelves for 10, 20, or more years—long after they have ceased to be of any use, and some may actually have seriously or dangerously deteriorated.

Recently, a small college in central Pennsylvania replaced a 100-year-old chemistry building with a new one. A huge amount of stored chemicals, including reactive and explosive materials, had to be disposed of before the old building could be torn down. The disposal operation alone cost $35,000.

The question of how good a job colleges and universities are doing today in managing hazardous waste is difficult to answer, because the effectiveness of hazardous waste management programs varies enormously from school to school. In fact, some schools have essentially no program at all.

Martha A. Anderson, director of the University of Arizona's department of risk management and safety, believes that the larger research-oriented universities in the country are doing an excellent job of hazardous waste management. She is very concerned, however, about the programs at smaller colleges and universities. She believes that many professors are so absorbed in research and teaching that they place a very low priority on hazardous waste disposal.

The environmental safety officers of some large universities, as well as some environmental safety consultants, often make scathing remarks about how hazardous waste disposal is conducted at many small colleges. But they also note that, although hazardous waste disposal currently is handled quite poorly in many schools, the situation is improving. Schools are increasingly aware of the need to improve waste disposal practices and of the impact of hazardous wastes on human life and the environment.

Important to note is the fact that most colleges and universities, including the largest ones, do not perform the ultimate task of disposing of hazardous wastes. The schools segregate wastes by type, assemble them for pickup, and sometimes package them in special drums. But the job of treating, storing, and disposing of the waste is often left to a commercial firm that specializes in this type of work.

In coping with hazardous waste disposal, many schools, especially small ones, face myriad problems. Finding the funds to do a proper job of hazardous waste disposal is difficult. Some critics, however, argue that the problem is not so much a matter of a shortage of money as it is a shortage of motivation. Howard H. Fawcett, a chemical health and safety consultant in Wheaton, Md., declares, "If the smaller schools had a real desire to do a good job, they could find the money somewhere. Often, the amount of money needed is not all that great—perhaps a few thousand dollars a year."

Another problem is that many small schools have no one working even part-time to coordinate the waste management program. In some schools, the person in charge of hazardous waste management is merely a member of the campus security force who is far more concerned about the theft of word processors from the administrative offices or the spraying of graffiti on campus buildings.

Alan S. Corson, chief of the studies and methods branch of the Office of Solid Waste at the Environmental Protection Agency (EPA), believes that many schools have only a vague idea of what RCRA or the states require in the way of hazardous waste management. "They often do not realize what their legal obligations are," he says. "And some schools are under the misguided impression that Congress never intended the law to apply to colleges and universities." He adds, "To someone not accustomed to reading government regulations, which sometimes are quite convoluted, the RCRA requirements are admittedly not easy to understand."

Because many schools generate relatively little haz-

Vermiculite poured into a lab pack will reduce breakage and absorb any liquid that may be released if a container inside does break

HAZARDOUS
WASTE
POISON

Label is attached to indicate that drum contains hazardous waste ardous waste, federal and state regulatory agencies have largely ignored most of them. As a result, some schools have felt no great compulsion to adhere to the law.

Laboratories in industry generally are considered to do a better job of waste management than those in academia. They usually have more money to spend on waste management than do academic labs. And directors of industrial labs usually get stronger backing from top managements for effective waste control than do the heads of academic departments. One reason is the companies' greater concern about their long-term financial liability.

Many academic research groups, in fact, regard themselves as essentially autonomous and operate with relatively little outside supervision. As a result, they may not pay attention to instructions from a department head or from the director of the university's environmental safety office. Industrial scientists are likely to be much more accustomed to following instructions from higher levels in the organization.

Aaron K. Furr, head of the department of health and safety at Virginia Polytechnic Institute & State University, observes, "Whether individuals are insensitive to environmental concerns or whether they simply feel that such issues interfere with their academic freedom, a campus program may be met with considerable resistance."

Another observer adds, "Industrial laboratories have had a long-standing reputation for being more safety conscious than academic labs. In industry, people who repeatedly disobey safety rules get fired. In universities, some professors take an extremely cavalier attitude toward the matter because, after all, they have tenure."

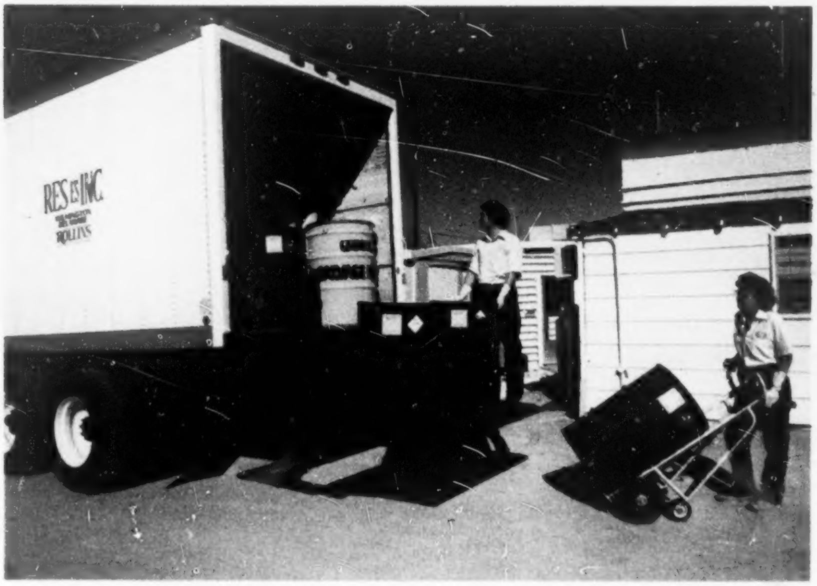
Jay A. Young, a chemical safety and health consultant in Silver Spring, Md., declares, "When it comes to the operation of hazardous waste management programs, some professors can get quite obstructive because of their absurd assumption that they know much more about the problem than do the university's environmental safety experts. You find this attitude much less often in industry."

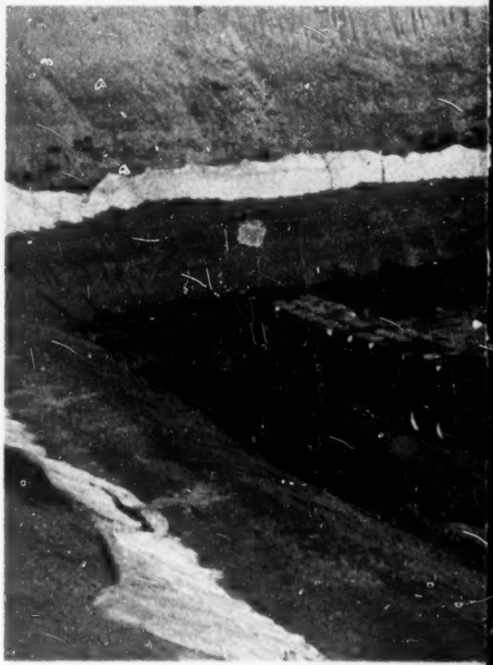
As hazardous waste generators, academic labs, of course, are very different from industrial plants. Academic labs generate only a very small percentage of the total amount of hazardous wastes produced in the U.S. According to EPA, generators of less than 1000 kg per month of hazardous waste—a category into which most academic labs fall—account for just 0.4% of all such waste, or only about 940,000 metric tons a year.

On the other hand, academic laboratories produce an exceptionally large variety of waste. An industrial plant may generate only a dozen or so waste products. An academic laboratory may generate thousands of such products, some in only gram quantities. Not only is the waste varied but it continually changes in composition as new research projects are started, older projects terminated, and the direction of research programs shifted.

For example, in 1984 the University of Illinois disposed of 7300 containers holding more than 2100 different chemicals and chemical mixtures. The University of Massachusetts, Amherst, annually disposes of about 2000 different chemicals and chemical mixtures. They range in amounts as small as an ampoule to as large as a 55-gal drum.

This wide diversity of chemicals is a major problem, partly because EPA requires that all chemicals buried in landfills be identified by chemical name. The identification of wastes, which may require chemical analysis if identifying labels are missing, obviously is a more





Drums of packaged and identified hazardous wastes (above) are loaded on a truck that will transport them to a landfill (right), where they will be buried complex, expensive, and time-consuming job for an academic lab than for an industrial plant that generates only a few types of waste. The cost of having a waste analyzed in a university lab typically ranges from $30 to $50.

In addition, the great variety of waste generated by academic labs requires them to do an exceptional amount of paperwork to keep tabs on what they ship to off-site disposal facilities. This also is a serious problem for waste disposal firms. The waste disposal firm that Washington State University has used for many years recently notified the university that it no longer would handle the school's hazardous waste. The company claimed that, although the university's waste represented only about 1% of the company's business, it accounted for about 99% of its problems.

The hazardous wastes generated by academic labs run the gamut from organic solvents, heavy metals, and explosives to flammable compounds, toxic materials, corrosive substances, and carcinogens. Typically, the largest volume of waste generated by these labs consists of organic solvents.

EPA has established special rules for so-called "acutely hazardous wastes" that, unlike those that have chronic toxicity, can cause serious harm from a single or a short-duration exposure. Among such chemicals are sodium cyanide, carbon disulfide, fluorine, arsenic trioxide, and mercury fulminate.

EPA may allow a facility to store, for example, up to 100 kg of an ordinary hazardous waste without a permit. However, it will allow the storage without a permit of no more than 1 kg of a waste that is acutely hazardous.

The amount of hazardous waste chemicals generated at some universities is larger than might be imagined. And the amount is growing. For instance, in 1984 the University of Illinois campus generated about 27,500 kg of such chemicals. In 1985, the amount climbed to 37,000 kg. The University of Wisconsin, Madison, disposed of about 50,000 kg of such waste in 1984 and about 105,000 kg last year. The University of Maryland, College Park, increased its hazardous waste shipments to an outside disposal firm from about 150 55-gal drums in 1980 to 320 drums last year.

One of the major problems that colleges and universities are facing is the rising cost of their hazardous waste disposal programs. The University of Illinois spent about $2000 to dispose of 100 drums of waste chemicals in 1977. By 1982, its cost of disposing of 265 drums was $46,000 (or more than $17,000 per 100 drums). By 1985, the cost of disposing of 216 drums was $51,000 (or about $24,000 per 100 drums).

In 1985, the University of Virginia spent about $17,000 to have part of its hazardous waste disposed of by a commercial firm. This waste was only about one third of the total generated by the university, since the remainder was handled by the school's own recovery and treatment procedures. In contrast, the university spent only about $7000 in 1980 to have all of its hazardous waste disposed of by an outside firm.

In late 1983, Richard S. Holdstock in the environmental health and safety office at the University of California, Davis, estimated that the cost of collecting and removing hazardous waste from the campus had grown 113% in the previous five years. The principal reasons for this rise were the increases in labor costs and in the volume of waste handled. He estimated that the total cost of collecting, storing, segregating, packaging, shipping, and disposing of hazardous waste in a single 55-gal drum was about $104 (a cost that has risen considerably since then). Of this dollar amount, 43% represented the cost of labor.

John P. Nemergut of Science & Engineering Associates, a research organization in Albuquerque involved in hazardous waste management and environmental planning, comments, "Transportation and disposal costs of hazardous wastes have skyrocketed to a point where, for some chemicals, they actually can exceed their purchase price."

Paying for hazardous waste disposal

At the vast majority of colleges and universities, the cost of hazardous waste disposal is treated as a general operating expense. One reason for dealing with hazardous waste disposal as an indirect cost is the difficulty in determining exactly how much of the total cost should be assigned to each academic department.

In recent years, a growing number of people have been arguing that the cost of hazardous waste disposal should be treated, instead, as a direct cost that can be tied to a department's operations. They say that it is unfair to charge the English department, for example, for the cost of hazardous waste disposal or even to charge the physics department almost as much as the chemistry department, which may produce far more such waste.

On the other hand, when waste disposal is treated as an indirect cost, scientists are encouraged to use the

Sites at two universities are on Superfund high-priority list for cleanup of wastes

The Environmental Protection Agency has placed both the University of Minnesota and North Carolina State University on its Superfund National Priorities List that calls for the cleanup of sites used for disposal of hazardous wastes in the past. Of the two schools, Minnesota is taking action to remedy the situation, and North Carolina has rejected EPA's allegations.

Between 1960 and 1974, the University of Minnesota burned chemical laboratory wastes in an outdoor pit at its Rosemount Research Center in Rosemount, Minn., about 25 miles south of St. Paul. The university stopped the practice in 1974 when it began sending its hazardous wastes to an outside company for disposal. Subsequently, the pit was covered over.

In 1984, the Minnesota Pollution Control Agency, which handles the state's EPA program, found that groundwater as far as 2 miles to the northeast of the disposal site was contaminated with low levels (less than 15 ppb) of chloroform. About 30 families live in this contaminated area. The agency advised the families to stop using well water because, among other things, chloroform can cause liver damage. The university, at the request of the Minnesota Department of Health, began supplying the families with bottled water for drinking and cooking.

The university has suggested several ways of solving the water contamination problem. Fay M. Thompson, the university's hazardous waste officer, regards three as especially promising.

One is to install charcoal filters at each home to adsorb the chloroform. Another is to drill near each house a new well deep enough so that its water contains no chloroform. A third possibility is to set up a community supply system that obtains water from outside the contaminated zone. No decision has yet been made by the pollution control agency in cooperation with the state's health department.

Chloroform, unlike many organic compounds, does not biodegrade once it gets into the ground. And because it is water soluble, it can readily enter underground water supplies. Hence, although many chemicals were placed in the Rosemount burning pit, only chloroform appears to have seeped out in hazardous concentrations. Thompson expects the university's problem to be solved by the fall of this year.

Bruce S. Davis, a project manager at the Minnesota Pollution Control Agency, says that, actually, a number of other chemicals, such as carbon tetrachloride, 1,2-dichloroethane, and 1,1-dichloroethylene, also have been found in groundwater in the vicinity of the burning pit, but in concentrations that are permissible in drinking water.

Several other waste disposal sites at Rosemount currently are being investi-

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best methods available for dealing with it because the disposal will cost them the same, regardless of what practice they follow. In other words, the indirect-cost system discourages people from flushing chemicals down a drain just to reduce their hazardous waste disposal costs.

Some schools, particularly smaller ones, have undertaken cooperative ventures to reduce their waste disposal costs. Schools in a given region use the same waste disposal company, which operates along a single designated route. Such a system reduces transportation costs because waste haulers often charge as much for transporting one drum of waste as they do for transporting a dozen. It also may enable the disposal firm to lower its price per drum because it is dealing with a larger volume of waste.

One of the more ambitious cooperative projects for hazardous waste disposal has been under way since 1981 in Minnesota, where high schools were accumulating sizable amounts of hazardous chemicals that they did not know how to get rid of.

The Minnesota Chemical Waste Assistance Project now serves about 160 high schools and 20 colleges throughout the state. The schools periodically bring their hazardous waste to any one of five regional collection sites, where people from the University of Minnesota pick it up and ship it to the university for handling. The program, which last year cost the participating schools about $50,000, enables small schools to dispose of their hazardous waste safely at relatively low cost. In addition, a program has been set up so that schools needing specific chemicals can obtain them without cost from schools that want to get rid of them.

To manage hazardous waste chemicals on college and university campuses, the waste first must be assembled at one or more locations, segregated by type, and, if necessary, labeled. After the material has been stored on campus usually for no more than 90 days, it is picked up by a waste transporting firm or by a waste disposal firm.

Before being transported off the campus, the waste containers usually are placed in 55-gal drums, which can be buried in landfills. In some cases, the waste is treated to reduce its volume or to make it less hazardous before it is buried.

Use of lab packs

In early 1985, EPA began prohibiting the burial of hazardous liquid wastes in landfills. This ruling, however, did not affect the previous EPA regulation, issued in late 1981, that allowed the burial of laboratory-generated liquids (as well as solids) in lab packs.

The lab-pack ruling, which recognized the special problems of labs, is encouraging to many lab people who think that EPA also should ease some other rules that place excessive burdens on lab operations.

A lab pack is a 55-gal drum that is capable of holding no more than 15 gal of liquid waste in bottles or cans. The remaining content of the drum consists of an inert, absorbent material, which is usually vermiculite but also can be diatomaceous earth or fuller's earth.

The filler material reduces the possibility that the containers will break by accidentally hitting one another. It also can absorb any liquid that is released if a gated by the pollution control agency. These, however, are not expected to be so serious a health or environmental problem as the one primarily involving chloroform.

The issue at North Carolina State University stems from the fact that a large variety of bottles, cans, and other containers of waste chemicals were buried between 1969 and 1980 at an off-campus site about a half-mile north of its Carter-Finley Stadium. These materials, which came from the school's science laboratories and agricultural research facilities, included organic solvents, pesticides, heavy metals, acids, and bases.

In 1982, the university's department of marine, earth, and atmospheric sciences began drilling a series of wells near the disposal site to determine whether the groundwater contained hazardous chemicals. To date, it has drilled 24 wells to depths ranging from 30 to 65 feet. Shortly after it began its test program, the department found that the water contained relatively high concentrations of such compounds as chloroform, bromoform, 1,1,1-trichloroethane, and methylene chloride.

Test wells have been drilled as far as 250 feet from the disposal site. According to Charles W. Welby, a hydrogeology professor at the university, the contaminating chemicals have been found only at distances of less than 100 feet from the disposal site.

This location, he emphasizes, is almost completely surrounded by state-owned property and consists largely of forested and grassy areas. No homes are on this land. On the other hand, parts of the area are used for parking cars, especially during football games.

NC State has appealed EPA's designation of its disposal area as a Superfund site and has asked to be removed from the National Priorities List, which identifies sites for long-term cleanup. Welby says that the school has received no formal response from EPA regarding this appeal. The university is monitoring key wells near the site to determine the water's concentration of specific organic chemicals. Welby declares, "We are confident that the groundwater contamination is having no impact on human health. The nearest family that could possibly be affected is more than a mile away from the disposal site. And the contamination plume goes out for less than 100 feet—in a direction away from the populated area."

Nevertheless, Al J. Smith, a Superfund coordinator in EPA's Atlanta office, says the agency still regards the NC State site as a potential hazard to health and the environment. He stresses that the plume can spread in the future. Moreover, the university someday may wish to use the area for purposes that could be endangered by the underground contamination.

container breaks—liquid that otherwise might leak out of the drum. Lab packs are used both to transport discarded chemicals to a waste disposer and to hold the chemicals when deposited in a landfill or placed in an incinerator.

If the drum will be buried in a landfill, it must be made of metal. However, if it will go into an incinerator, it can be made of fiberboard or other burnable material.

The drum must hold only materials that are chemically compatible. Moreover, they cannot contain such unusually dangerous materials as organic peroxides, reactive metals, or explosives.

The majority of hazardous waste from laboratories now is buried in lab packs. The method is relatively simple and, compared to incineration, fairly inexpensive. On the other hand, lab packs usually cost anywhere from $300 to $400 each, including the cost of the drum and the absorbent filler and the costs of packing, inventorying, shipping, and burying it. The cost of packing, shipping, and disposing of lab packs has increased about two- to threefold in the past four years. Moreover, some waste disposal firms refuse to handle only one or two lab packs or they may charge as much for shipping five drums as for shipping a full truckload.

Some universities pack their own lab packs to save money. But many waste disposal firms insist on packing all the lab packs they accept. This not only increases their profits but it ensures that the job will be done correctly.

Not long ago, a shudder went through the waste management industry when one disposal company in New Jersey that had not packed the lab packs it handled incinerated the contents of one of them. Because the company did not realize that the drum improperly contained an explosive, a costly incinerator was demolished.

Many waste management experts have misgivings about burying lab packs in landfills. They point out that the method does not really dispose of the wastes; it merely hides them. In addition, it is becoming an increasing financial burden. And even though lab packs generally are regarded as safe storage containers, it is always possible that some may leak.

One alternative, however, is incineration, which is decidedly expensive. For example, the incinerator currently being built at Stanford to handle up to 1000 lb of solid and liquid wastes an hour will cost about $850,000, including the cost of a wet scrubber and instrumentation. Use of incinerators is expensive not only because of the equipment but because of the cost of the skilled labor required to operate them, the cost of the fuel needed to heat them, and the cost of carrying out the elaborate, time-consuming tests needed to get an EPA or state permit for their use. In addition, the resulting ash, which contains salts, metals, and other noncombustibles, usually must be stored in a landfill.

To win EPA approval, an incinerator must destroy or remove 99.99% of the principal organic hazardous constituents of the waste. And getting EPA's approval is far from easy. For one thing, the repeated test burns that must be carried out before EPA is satisfied that an incinerator is working properly may take a year or more. The head of an environmental safety department at a large university groans, "Frankly, the job of getting our incinerator permit nearly killed me!"

Despite the hassle, a few large schools, such as the University of Wisconsin and the University of Arizona, already have installed a waste incinerator on or near their campuses. The University of California system is looking into the possibility of building several regional incinerators to destroy the hazardous wastes from its numerous campuses.

But one university expert concludes that the majority of academic institutions cannot afford to operate their own incinerators for hazardous waste disposal. Recognizing, however, that the method has many environmental advantages, he recommends that several schools within a relatively limited area jointly install a single incinerator for their cooperative use.

Some large schools have disposed of some flammable waste solvents in the past by adding them to the fuel oil used to heat steam boilers, power generators, or incinerators.

This practice, however, is declining, mainly because of increased regulation by federal and state agencies. Also, the practice may involve more cost and effort for schools than it is worth.

Starting in 1982, the University of Virginia got rid of its waste xylene by burning it as a secondary fuel to heat the incinerator it used to destroy pathological wastes. Now, the university finds it more practical to give its waste xylene and other flammable solvents away free to a company that adds them to its heating fuel.

Some years ago, Texas A&M University used such flammable waste chemicals as acetone and methanol to augment the fuel oil used to heat an incinerator. Last September, however, the university discontinued this practice when Texas enforced regulations stating that only boilers or industrial furnaces (but not incinerators) can be used without a RCRA permit to recover energy by the burning of flammable hazardous wastes.

Another way to reduce waste is to use electrolysis where feasible. Schools that have large photographic and x-ray facilities use electrolysis to recover valuable silver, for example. Other major schools send silver-containing solutions to commercial firms that specialize in recovering this metal.

Laboratories at a number of schools, including Southern Illinois University, Iowa State University, and the University of Arizona, decrease the volume of their hazardous waste by evaporating water or other solvents. The volume of aqueous solutions containing ions of such metals as chromium, lead, copper, and selenium can be greatly reduced by placing them in evaporating pans out-of-doors in warm weather (protected from the rain). The method, however, is quite time consuming.

Some labs also remove volatile solvents such as ethers by evaporating them in fume hoods. This procedure, however, can contaminate the outside air or pose a fire hazard.

A common way to destroy hazardous waste is to react waste acids and bases and thus neutralize them. If aqueous solutions fall within the pH range of 2 to 12.5 and do not contain any of the specified forbidden compounds, they can be poured down a drain, perhaps after being diluted.

A chemist at Rollins Environmental Services in Logan Township, N.J. analyzes a sample of hazardous chemical waste

At some universities, the hazardous waste office will not accept waste acids and bases. They must be neutralized in the lab and disposed of in a sewer. If not enough discarded base is available to treat the waste acid, a relatively inexpensive base such as sodium bicarbonate is used.

Organic solvents often are recovered from contaminated solvents by distillation, both to lessen the amount of chemicals that need to be purchased and to reduce the cost of hazardous waste disposal. But many schools do not want to get involved in distilling waste solvents because the job is time consuming and costly and many solvents are quite flammable.

RCRA requires that anyone who operates a facility for treating specified hazardous wastes must have an EPA or state permit. Such treatment procedures include distillation, neutralization, evaporation, and chemical conversion. However, these rules frequently are ignored by academic labs. Moreover, EPA has not been particularly diligent in imposing its rules on academic labs because they generate so relatively little hazardous waste.

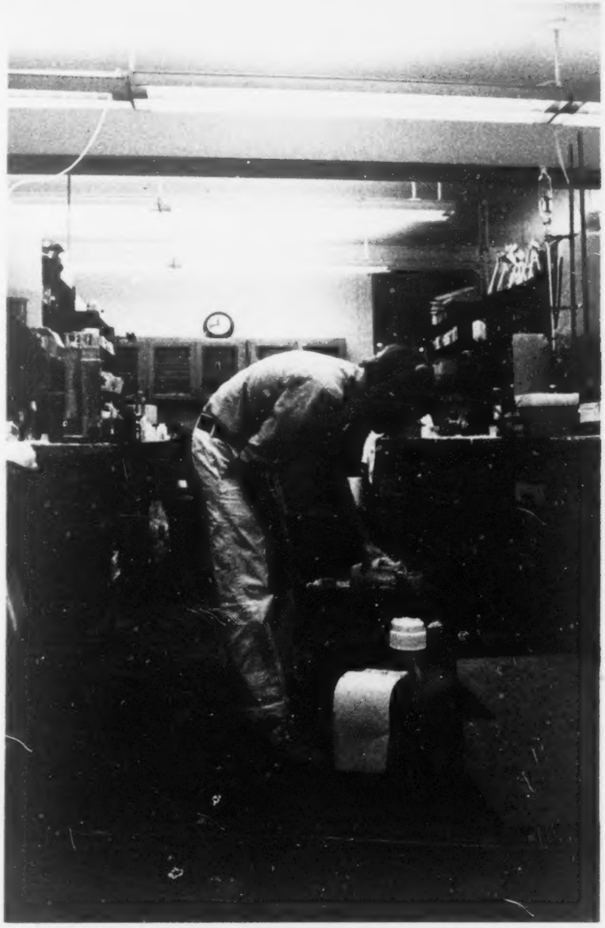
In some cases, toxic chemicals can be converted to nontoxic compounds. One example is a cyanide salt, which may be detoxified in the lab by treating it with an oxidizing agent such as sodium or calcium hypochlorite to produce a biodegradable cyanate. (This, of course, must be done under proper ventilation to avoid exposure to the poisonous cyanide.) The resulting cyanate usually can be flushed down the drain.

Relatively few academic labs, however, follow such a procedure. The time and effort involved are considerable. And many scientists are reluctant to deal, any more than absolutely necessary, with substances as toxic as cyanides. On the other hand, the new hazardous waste facility being built at Stanford will include a laboratory where poisonous compounds such as cyanides and carbon disulfide will be converted to nontoxic substances before disposal.

The University of Wisconsin has a centralized facility that, among other things, detoxifies hazardous wastes. For example, it uses saponification to detoxify organophosphate pesticides. The facility also contains labs that can neutralize acids and bases, reduce oxidizing agents, or precipitate heavy metals. The installation has applied for an EPA permit to carry out such procedures.

Wastes containing explosive chemicals present special problems to schools. Among such compounds are picric acid, organic peroxides, perchlorates, hydrazine compounds, and ethers that have deteriorated to form explosive peroxides. These dangerous materials are not permitted to be buried in landfills. Furthermore, many waste disposal firms will not handle them. Those that do may charge as much as $500 a lb to dispose of them because of the risks involved and the high cost of liability insurance.

Some academic labs donate their explosive chemicals to the bomb squad of their local police department for training purposes. One school in the Boston area, however, ran into trouble when it repeatedly turned over its explosive compounds to a nearby Army depot for detonation without being charged for the service. A Boston company that specializes in disposing of explosive chemicals successfully sued the Army for unfairly taking away part of its business.



University of Wisconsin student pours waste solvent into carboy for disposal in university's incinerator

Universities can cut down their volume of discarded chemicals by operating systems to transfer chemicals from people who no longer need them to people who do. Russell Phifer of Resource Technology Services estimates that about 30 to 40% of all unused reagents can be used by another lab possibly within the same organization. Peter C. Ashbrook, head of hazardous waste management at the University of Illinois, says, "A surprising amount of the chemicals we receive for disposal are perfectly good—sometimes even in unopened containers. For more than 20 years now, our organic chemistry department has operated, on a voluntary basis, a stockroom containing usable chemicals that some of our scientists no longer want."

A chemical exchange program at the University of Massachusetts, Amherst, has been operating effectively for more than three years. As part of this effort, the environmental health and safety division issues a bulletin every two or three months to notify the school's scientists and engineers of the chemicals that are available. The program has saved the university more than $30,000 in the cost of new chemicals and of hazardous waste disposal by an outside firm.

A similar program has been under way at the University of Wisconsin since 1980. The hazardous waste office distributes a list of available donated chemicals five times a year. The project, says Peter A. Reinhardt, supervisor of the hazardous waste program, saves the school more than $20,000 a year by reducing chemical purchases and the costs of waste disposal.

About twice a year, Cornell University's chemistry department issues a list indicating what excess chemicals are available free from various members of the department.

Many researchers, however, may not want to run the risk of jeopardizing the success of an experiment by using a chemical that was not obtained recently in an unopened bottle from a chemical supplier. "Researchers clearly demand chemicals of known provenance," declares consultant Jay Young.

Edward W. Blackburn, director of the department of environmental safety at the University of Maryland, says that in 1980 the university began a program of collecting unopened bottles of excess chemicals and offering them free to other labs on the campus. The program, however, was discontinued after only about seven months because the faculty response was keenly disappointing. He believes the main stumbling block was that the university's scientists and engineers, by and large, want to use only freshly bought chemicals of unquestioned purity. He also emphasizes that the operation of a chemical exchange program is time-consuming and laborious.

Partly to reduce their volume of hazardous wastes, chemistry departments at some colleges and universities have been introducing lab courses that call for the use of unusually small amounts of chemicals. The scaled-down experiments also reduce the cost of needed reagents and permit experiments to be carried out that otherwise would be too expensive because of the high cost of the chemicals required.

Several years ago, Dana W. Mayo, a chemistry professor at Bowdoin College, and a pioneer in this area, developed an undergraduate organic chemistry lab course in which the volume of starting chemicals is one hundredth or less of the amount conventionally used. For the past two years, Princeton University has been using microscale experiments in its freshman inorganic chemistry lab courses. And Cornell University this semester decreased the scale of all of its undergraduate organic lab experiments one fifth to one tenth of the customary level. "We think this is an important step in the right direction," says Earl Peters, executive director of the chemistry department.

Most hazardous waste is produced by largest generators

Hazardous waste generated per month	Number of hazardous waste generators	% of total	Amount of hazardous waste generated (metric tons per year)	% of total
1000 kg or more	14,100	2.2%	264,000,000	99.6%
More than 100 kg but less than 1000 kg	175,000	27.4	700,000	0.3
100 kg or less	450,000	70.4	240,000	0.1
TOTAL	**839,100**	**100.0%**	**264,940,000**	**100.0%**

Source: Environmental Protection Agency estimates

Miles Pickering of Princeton's chemistry department emphasizes that microscale experiments are cheaper and safer than conventional ones. "Twenty grams of potassium cyanide is a serious hazard, whereas 100 mg is not likely to kill anyone." Pickering also points out that, when experiments are done on a small scale, reactions go faster, as do separation procedures.

Professors in some schools, however, are dubious about the practicability of introducing microscale experiments. Many students would be frustrated by such experiments, because they lack the manual dexterity to carry out the experiments successfully.

Many colleges and universities believe that some of EPA's RCRA regulations are too stringent for laboratories, as are state regulations patterned after those developed by EPA. They stress that RCRA was enacted almost entirely with industrial hazardous waste disposal in mind. They contend that rules that are perfectly justifiable for industrial plants, which generate tons of hazardous wastes, often are unreasonable for labs, especially those in academia.

Kathleen A. Ream, head of the American Chemical Society's department of government relations and science policy, asserts, "No one argues about whether there is a need for RCRA. Arguments can be made, however, that the burdensome nature of many of its regulations, which were designed with manufacturing or processing operations in mind, have hindered the primary function of laboratories—to advance scientific knowledge—while contributing relatively little to safe waste disposal."

One of the most frequently heard complaints is that EPA's regulations under RCRA demand an excessive amount of detail regarding the chemical composition of hazardous wastes generated by labs.

William G. Mikell, environmental control manager at Du Pont, says, "Even small-quantity generators, who are exempt from many RCRA regulations, may find that, when they go to ship their waste for disposal, they must describe it in some detail. This requirement on small-quantity research samples seems like overkill."

Phifer of Resource Technology Services comments, "The costly analytical testing of complex laboratory samples is a ridiculous way to use up a budget for waste disposal."

Various scientists concerned with environmental health and safety have been recommending that lab packs be required to identify their contents only by broad categories, such as corrosive acids, corrosive alkalies, oxidizing agents, flammable liquids, flammable solids, water-reactive compounds, polymerizable compounds, reactive organic peroxides, or toxic wastes. Such a change would reduce the amount of analytical work that colleges and universities are now required to do. Also, it would reduce the amount of paperwork that EPA would have to deal with.

Explosive wastes from University of Maryland are placed in this pit before they are detonated

But other environmental safety people are opposed to the use of broad chemical categories to identify hazardous wastes. Lawrence A. Holbrook, head of the hazardous waste management section of the University of Maryland's department of environmental safety, declares, "Broad classifications do not provide enough specific information to assist people in determining a material's full adverse effects on the environment. Many chemicals have more than one property. For example, crotonaldehyde, although officially classified as a flammable liquid, is also toxic. Hence, if you categorize a lab pack containing this chemical and other such liquids as holding only flammable materials, you may not realize that at least some of the contents are also poisonous."

Others believe that EPA should relax its rules governing its granting of permits to universities that want to operate their own incinerators for disposing of hazardous wastes. They believe that schools should be allowed to operate incinerators handling less than 25 kg per hour under less stringent requirements.

Present rules regarding the on-campus location of such units, the instrumentation required, and the testing necessary, they believe, are excessive. Says one university official, "Given the comparatively small quantities of waste involved on college campuses, it might be reasonable for EPA to relax its present standards requiring 99.99% destruction efficiency for all incinerators, including the relatively small ones."

EPA currently is considering the possibility of making its requirements for small incinerators less strict than for larger facilities. Academic people also argue that EPA should eliminate some of its rules requiring universities to have permits to treat hazardous wastes. In recent years, ACS has taken an active role in pointing out to EPA and other government agencies the special problems that laboratories have in dealing with government regulations covering hazardous waste. ACS has submitted a number of suggestions to EPA on how it can protect human health and the environment without imposing unreasonable hardships on labs.

It encouraged EPA, for example, to allow liquid hazardous wastes to be buried in landfills, provided they are stored in approved lab packs. It also has urged revision of other EPA regulations to make them more appropriate for labs. Some of these recommendations are currently under the agency's active consideration.

In late 1981, ACS established its Task Force on RCRA, headed by Stanley H. Pine of California State University, Los Angeles, as a joint effort of the ACS Committees on Chemical Safety, on Chemistry & Public Affairs, and on Environmental Improvement. Last year, the task force issued a 16-page booklet called "Less Is Better: Laboratory Chemical Management for Waste Reduction." (Single copies are available free by writing to the Office of Federal Regulatory Programs, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036.) □

Reprints of this C&EN special report will be available at $5.00 per copy. For 10 or more copies, $3.00 per copy. Send requests to: Distribution, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. On orders of $20 or less, please send check or money order with request.

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Chemical Industry Not Enthusiastic Over U.S.-Canada Free Trade Talks

U.S. industry leaders seem more concerned about what they may lose, seeing only additional competition and little or no market gains

Earl V. Anderson, C&EN New York

In an earlier article (Sept. 23, 1985, page 7) C&EN indicated that Canadian Prime Minister Brian Mulroney would soon approach the U.S. with a proposal for negotiations aimed at freeing trade between the two countries. It also analyzed the Canadian chemical industry's attitude toward freer trade with the U.S.

Three days after that article appeared, Mulroney did, in fact, phone President Reagan suggesting that Canada and the U.S. explore the scope of and prospects for a new trade agreement. Mulroney wanted to aim for the "broadest possible package of mutually beneficial reductions in barriers to trade in goods and services."

As expected, President Reagan welcomed Mulroney's proposal. On Dec. 10, as required by law, he formally notified Congress that he intended to enter into negotiations on a bilateral free trade arrangement with Canada. It's very likely that these negotiations will start soon—probably this spring.

With its strong interest in international trade, the U.S. chemical industry naturally has been following the U.S.-Canada free trade developments closely. This article takes a look at how the industry feels about them.

In 1911, Canada and the U.S. negotiated the Reciprocity Agreement, which would have reduced tariffs substantially in both countries. But before the agreement could be ratified in either country, a Canadian election intervened. The rallying cry in Canada was, "No truck nor trade with the Yankees." And the ruling Liberal government at the time was resoundingly voted out of office for its attempt at freeing trade with the U.S.

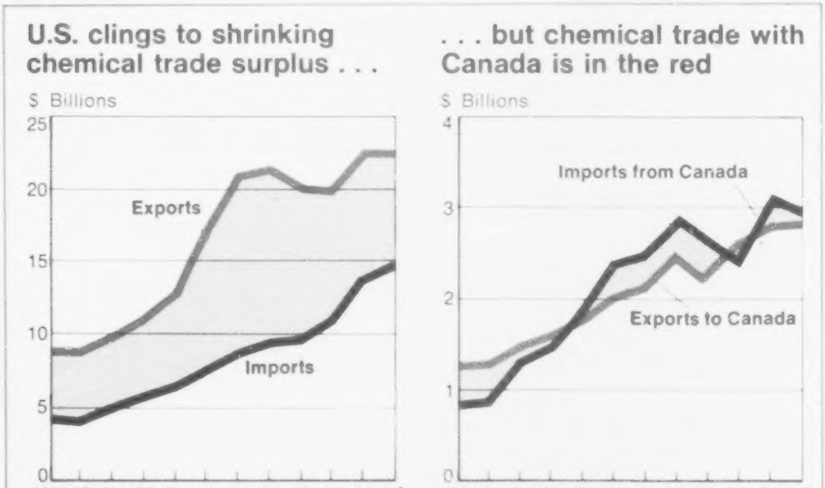
Now, 75 years later, the Canadians have initiated the idea of free or freer trade between the two countries. Again, it is a hot political and economic topic, both north and south of the border. Within the U.S. chemical industry, no one is running around crying, "No truck nor trade with the Canadians." But there is no visible groundswell of support for the concept coming out of the industry either.

To be sure, a few embrace the principle of unvarnished free trade, no matter what its shape or form. And because Canada is the U.S.'s largest trading partner, those people think it only reasonable that the two should get together at the bargaining table. In the chemical industry, however, they are the minority.

At the other extreme, some people emphatically oppose any attempt to negotiate an agreement that would make it easier for Canadian chemicals to move into U.S. markets. They are not looking at principles; they are looking at products. And when they compare the size of the Canadian market with the U.S. market, which is 10 times larger, they wonder how a free trade agreement could possibly benefit them.

Attitudes such as these are the extremes, but it's not difficult to find a few of them scattered throughout the U.S. chemical industry. Neither one, however, can be construed as representing the industry's position on the pending trade talks.

In the strict sense of the word, the industry has no position. In general, it is less than enthusiastic about the pending U.S.-Canada free trade talks. Another generality: Basic, commodity petrochemical producers tend to be less enthusiastic (or more opposed) to the idea of U.S.-Canadian free trade than producers of downstream products. Not surpris-



U.S. clings to shrinking chemical trade surplus . . .

. . . but chemical trade with Canada is in the red

a C&EN estimate. **Source:** U.S. Bureau of the Census

Canada is a major U.S. supplier for fertilizer, inorganics, and radioactive materials

	U.S. chemical exports			U.S. chemical imports			Trade balance	
$ Millions	World	Canada	% Canada	World	Canada	% Canada	World	Canada
Organic chemicals	$ 6,050	$ 662	10.9%	$ 4,604	$ 576	12.5%	$1446	$ 86
Inorganic chemicals	2,172	302	13.9	1,983	720	36.3	189	−418
Radioactive & associated materials	1,263	17	1.4	1,346	420	31.2	−83	−403
Dyeing, tanning, & coloring materials	133	34	25.6	347	3	0.9	−214	31
Pigments, paints & varnishes	332	112	33.7	246	30	12.2	86	82
Medicinals & pharmaceuticals	2,814	196	7.0	1,057	42	4.0	1757	154
Flavors, perfumes, cosmetics & toiletries	488	64	13.1	550	21	3.8	−62	43
Cleaning & polishing materials	310	50	16.1	159	45	28.3	151	5
Fertilizers, manufactured	2,105	182	8.7	1,013	711	70.2	1092	−529
Explosives & pyrotechnics	111	25	22.5	116	30	25.9	−5	−5
Plastics & resins	3,834	700	18.3	1,636	330	20.2	2198	370
Pesticides & disinfectants	643	137	21.3	434	15	3.5	209	122
Miscellaneous chemical products	1,905	319	16.8	984	57	5.6	921	262
TOTAL	$22,160	$2800	12.6%	$14,475	$3000	20.7%	$7685	$−200

Source: C&EN estimates based on 10-month data

ingly, that's the exact opposite of the feelings permeating the Canadian chemical industry. There, the basic petrochemical producers ardently push free trade with the U.S. The opposition comes from the downstream producers.

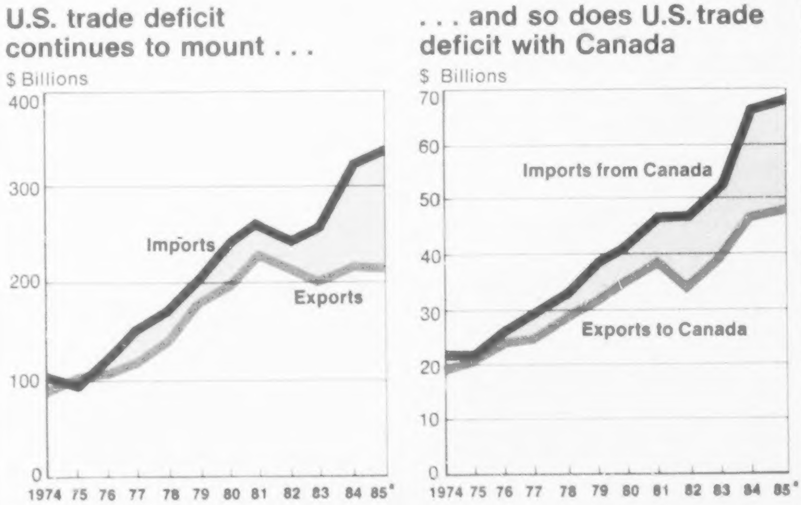
To varying degrees, basic chemicals producers in the U.S. see only additional competition and little or no new market opportunities. Some downstream producers see less-expensive raw materials and the possibility of additional markets.

But the generalities end there. When specific products are mentioned, companies tend to have a more specific attitude. Producers of polyethylene and styrene, for instance, do not want to see tariffs on those products eliminated for Canadian imports. According to one trade expert who knows well the pulse of the chemical industry on trade matters, Canada-U.S. free trade has been, until now, almost a nonissue for the chemical industry. No leading industry spokesman has come out and flatly denounced it. That's just not the statesmanlike thing to do. On the other hand, nobody has gone resolutely to bat for it either.

Now, however, U.S.-Canada free trade looms as a significant issue for the chemical industry. With the negotiations likely to begin around May, the industry trade experts who interface with official Washington are gearing up to protect their industry's flanks. Until recently, the chemical industry's major input into the government's preparation for trade negotiations with Canada has been a set of principles compiled last year by the Chemical Manufacturers Association. Those principles do not concern specific chemical products, or chemical industry sectors. Instead, they are issues that CMA believes the U.S. government should address before entering into any bilateral free trade agreement with Canada.

Just last week, however, the Industry Sector Advisory Committee for Chemicals (ISAC-3) sent to U.S. Trade Representative (USTR) Clayton Yeutter a "refined" set of principles based on CMA's earlier work. ISAC-3 is one of many ISACs formed during the Tokyo round of multilateral trade negotiations, which ended in 1979, to funnel industry information and opinion into the trade representative's office.

ISAC business is confidential, but indications are that ISAC-3's refined principles don't stray too far from the framework provided by CMA. One major difference: Although the new ISAC principles focus particularly on the U.S.-Canadian trade



a C&EN estimate. Source: U.S. Bureau of the Census talks, they can be adopted for bilateral negotiations with almost any nation.

Some of CMA's principles are pretty straightforward. CMA believes, for instance, that a bilateral free trade agreement with Canada should confer balanced benefits to both countries. One country should not end up with a better deal to the detriment of the other.

Almost everyone acquainted with U.S. and Canadian trade anticipates that the bilateral trade talks will include a healthy dose of tariff cutting. In fact, negotiators may attempt to eliminate tariffs completely on trade between the two countries.

Most of that trade already is duty free. Those tariffs that remain are mostly on manufactured products. On average, Canadian duties are higher than those in the U.S. tariff schedule. However, CMA doesn't think the negotiations should become only an exercise in tariff cutting. They also should address nontariff barriers to trade. One in particular is Canadian energy pricing policies that give that country's petrochemical producers a preferential feedstock price advantage. Another is Canadian restrictions on foreign investment.

Both issues are less onerous than they were even a year ago. The U.S. chemical industry's concern about Canada's internal energy policies was shaped in the early 1980s when the Liberal government of then-Prime Minister Pierre Trudeau launched its National Energy Policy. At the time, right after the second oil crisis, world prices for crude oil were skyrocketing.

Canada's National Energy Policy was designed, among other things, to keep Canadian oil and natural gas prices below world or U.S. prices to protect Canadian consumers. It was molded to "Canadianize" the oil industry. And its tax and royalty provisions raised vast amounts of revenue for the federal government and the energy-producing provinces.

That policy also meant that Canadian petrochemical producers would have a distinct advantage in feedstock costs over their U.S. competitors. They enjoyed that advantage for only a short time, however. Pricing policies were based on the assumption that world oil prices would move steadily upward. When those prices later started dropping instead, the Canadian petrochemical feedstock advantage disappeared.

A little more than a year ago, Mulroney's Conservatives replaced Trudeau's Liberals in Ottawa. Since then, the National Energy Policy has been replaced by energy policies designed to bring flexible, market-oriented pricing back into Canadian oil and natural gas.

CMA recognizes, of course, that Canadian energy pricing policies have improved considerably in the past year. It also recognizes, however, that in government nothing is forever. Thus, CMA is cautioning the U.S. Trade Representative to make sure that present and future Canadian policies relating to petrochemical feedstock supply and price do not serve as a barrier to otherwise fair competition.

That same cautious attitude has been directed toward Canadian policies on foreign investment. During the Trudeau Administration, "FIRA" was a buzzword in foreign investment circles. FIRA stood for Foreign Investment Review Act. It also epitomized restrictive foreign investment policies.

One of the major objections to FIRA was that, to win approval for an investment in Canada, a foreign company had to agree to certain "performance" requirements, such as domestic sourcing for raw materials. Strictly Canadian companies did not have to meet those requirements.

Because of this, the U.S. submitted a complaint against FIRA to the General Agreement on Tariffs & Trade (GATT), the international body that sets the trade rules for most of the world's major trading nations. In 1983, GATT ruled that FIRA did, indeed, violate GATT Article III.

Just as it did with Canadian energy policies, the Mulroney government started changing foreign investment policies after it came into office. FIRA has been replaced by a much less restrictive Investment Canada Act.

However, in CMA's view, the new investment act is not lily white. Although the new legislation makes foreign investment in Canada much more welcome than FIRA did, some restrictions do remain, especially on foreign acquisitions of existing Canadian companies.

So, just as it did with Canadian energy policies, CMA feels it remains to be seen how the new legislation is implemented. Meanwhile, it wants U.S. negotiators to get rid of discriminatory Canadian investment restrictions (other than those dealing with national security) before they reach any tariff-cutting agreement.

Although energy-feedstock pricing policies and foreign investment restrictions head the chemical industry's list of important nontariff barriers, they are not the only ones. As actual trade negotiations draw closer, intellectual property rights figure to become a more important issue. In fact, intellectual property rights have become a hot international economic issue on a scale much broader than just U.S.-Canadian trade. U.S. companies, including many in the chemical and pharmaceutical industries, are annoyed because they are not receiving adequate protection for their intellectual property, such as patents and copyrights, in some countries. Without that protection, the companies claim they are losing the battle for international markets to unfair competition.

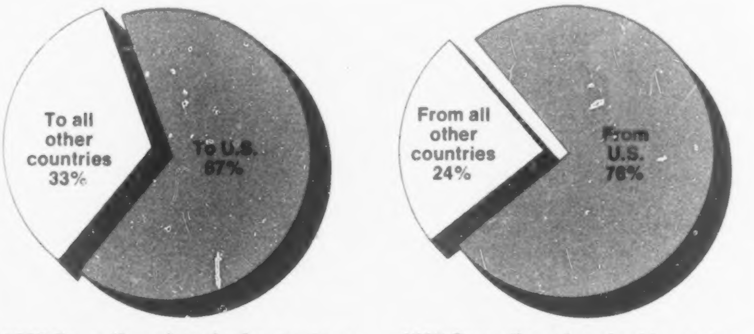
Congress has taken heed. It has written provisions aimed at encouraging such protection abroad into the Trade & Tariff Act of 1984. Intellectual property rights have been included in several previous bilateral trade and investment negotiations. In fact, some industry groups are pushing to have them included in the proposed multilateral trade negotiations.

CMA wants intellectual property right protection included as part of any free trade negotiations with Canada. Although Canada is far from the worst offender, there are some problem areas, particularly in pharmaceuticals.

For some time, in fact, major U.S. drug companies have been fighting against what they see as inadequate pharmaceutical patent protection in

U.S.-Canadian chemical trade

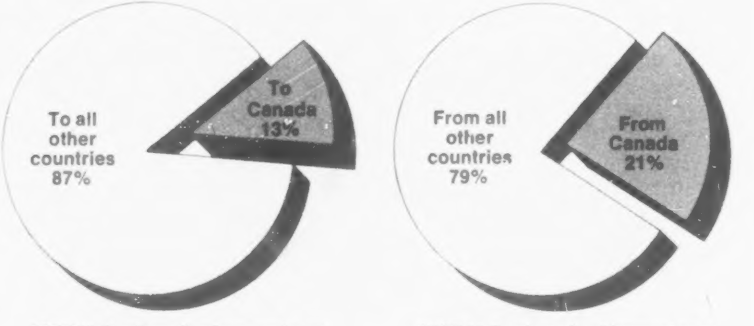
A much larger share of the total for Canada . . .



1985 Canadian chemical exports = $4.17 billion

1985 Canadian chemical imports = $4.04 billion

. . . than it is for the U.S.



1985 U.S. chemical exports = $22.16 billion

1985 U.S. chemical imports = $14.48 billion

Note: 1985 figures are C&EN estimates based on 10-month data from U.S. Bureau of the Census, Statistics Canada

Canada. They are peeved at old Canadian laws that allow generic drug companies to move swiftly in copying new drugs developed by multinational companies.

The Mulroney government is supposed to start reconsidering the pharmaceutical patent protection issue this year. Experts in the U.S., however, aren't optimistic about getting all of the changes they think are necessary. For instance, multinational drug companies—not just those based in the U.S.—want 17 years of basic patent protection. Informed betting is that the Mulroney government is considering eight years. That's much better than what exists today (virtually none), but it's far short of the multinationals' demands.

Canadian generic drug producers naturally are resisting any changes in the existing law. So are the provinces of Ontario and Quebec, which depend on less-expensive generic substitutes in their drug programs for the poor and elderly.

In the U.S., however, major U.S. drug companies argue that they are being robbed of years of research and development costs, not to mention lost profits. By now, officials at the trade representative's office have been made well aware that intellectual property rights is a contentious issue. There's little doubt that it will be on the agenda when the U.S.-Canadian trade talks begin.

Despite the importance of those and other nontariff barriers, tariff cutting will be the major chemical industry concern in the U.S.-Canada trade negotiations, just as it has been in virtually all past trade negotiations. It's possible that existing tariffs on chemical trade between the two countries will be eliminated completely during the negotiations. If that should happen, the chemical industry wants it to happen on as broad a base as possible.

This is a key issue for the chemical industry. If tariffs are to be eliminated completely, CMA wants it to be across the board—that is, it should include all chemicals and related products and not be limited to chemical industry subsectors or specific products. For the U.S. chemical industry, it is a logical position to take. Canada has tried several times to convince the U.S. to grant duty-free treatment to selected Canadian petrochemicals. The first attempt originated out of Alberta right after the Tokyo round ended in 1979.

At the time, energy-rich Alberta was starting to develop its world-scale petrochemical industry. The U.S. was scratching for oil and natural gas supplies. Alberta offered to supply the U.S. with natural gas in return for zero tariffs on several petrochemicals that the province was producing or planned to produce.

The Albertans took their proposal to Congress, but it never got off the ground. Later, when free trade negotiations between the two countries became a more serious topic, "sectoral" free trade was suggested as the approach with the best chance of success. After all, the U.S. and Canada already had a successful, 20-year trade agreement covering automobiles and parts.

One of the sectoral candidates proposed by the Canadians was again petrochemicals. Before this sectoral approach advanced very far, government reins changed hands in Ottawa. When the Mulroney government picked up the issue of free trade with the U.S., it adopted the broad-based approach.

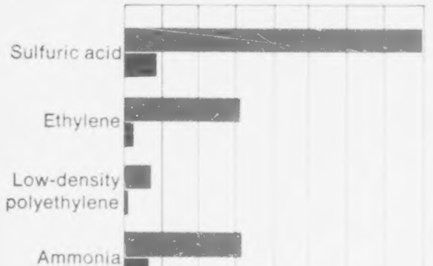
CMA favors such an approach for chemicals because it believes it is the only way that negotiators will be able to achieve reciprocity—or balanced benefits—in chemicals. Very few disagree that a free trade pact limited only to basic petrochemicals would benefit Canadian producers and hurt U.S. producers.

That could become a tough issue for negotiators to tackle. CMA's counterpart in Canada, the Canadian Chemical Producers Association, strongly supports free trade in petrochemicals. But CCPA is much less enthusiastic about duty-free trade in downstream products. Many of its smaller member companies believe they could be hurt badly if their domestic markets were opened to duty-free imports from the U.S.

CMA, meanwhile, believes its members could be hurt by one other aspect of a free trade arrangement between the U.S. and Canada. It is concerned that products from a third country that are dutiable in the U.S. could slip into the country duty free by way of Canada.

It's an old ploy. Producers in third countries could ship their products to Canada, where they would go through minor formulating or finishing operations. Then, by shipping them to the U.S. out of Canada, these products would sidestep U.S. tariffs.

U.S. output of chemicals towers over that of Canada



Sources: U.S. International Trade Commission, U.S. Bureau of the Census, and Statistics Canada

To prevent this from happening, CMA wants a minimum level of "Canadian value added" established as a condition for duty-free entry into the U.S. The value-added threshold, says CMA, should be high enough to prevent these unfair transshipments. CMA suggests a level of 70%. That's twice as high as the 35% value-added requirements set by the Generalized System of Preferences (GSP), which grants duty-free treatment to products of eligible developing countries. The Caribbean Basin Initiative, designed to give preferential tariff treatment to products from Caribbean countries, also has a 35% value-added provision.

But, as CMA points out, Canada is not a developing country. It should not be given the liberal domestic value-added requirements that developing countries are receiving under GSP and Caribbean Basin Initiative.

CMA suggests, however, that the value of raw materials or components shipped from the U.S. to Canada be considered "Canadian value added" in determining whether a Canadian product meets the 70% test. That, CMA says, will help to promote bilateral trade.

CMA has some other caveats about duty-free treatment of Canadian chemical imports. It believes that any free trade agreement should contain a "snap-back" provision, which automatically would return tariffs to their normal rates if any conditions of the agreement no longer are fulfilled. If, for instance, Canada reimposed investment restrictions or reverted back to unfair energy pricing policies, then duties of chemical imports from Canada would snap back to their normal rates.

Intent on protecting the industry's flanks, CMA has brought several other issues to the attention of the U.S. Trade Representative. It wants surcharges imposed to correct temporary distortions of trade caused, for instance, by currency fluctuations.

CMA also assumes that U.S. unfair trade statutes will continue to apply to imports from Canada. In other words, Canada's exports to the U.S. will continue to be subject to antidumping and countervailing duty laws designed to protect U.S. industries injured by unfair import competition.

That may be more hope than assumption on CMA's part. A major reason that Canada started the ball rolling toward free trade talks with the U.S. was its fear of growing U.S. protectionism. It hopes to insulate its exports to the U.S. from further protectionist action by getting special treatment for them, including possible exemption from the U.S. unfair trade practices statutes.

CMA also has suggested a few housekeeping provisions, such as an adequate and binding dispute settlement mechanism. It also recommends that U.S. trade officials consult with the chemical industry both before and during the negotiations.

On that score, at least, CMA's wish is already being fulfilled. Without exception, leading industry trade experts have given the trade representative's office high marks for its open-door policy. "The people over there are always ready to listen to us," says one chemical industry trade expert. Another, more cautious cynic adds, "Hearing and heeding are two different things."

The admiration is reciprocal. Top officials at the trade office have praised the chemical industry for its knowledge of trade issues. And they single out ISAC-3 as one of the most effective of all the industry sector advisory committees. To remain effective, ISAC-3 has its work cut out for it. In addition to polishing the arguments contained in CMA's set of principles, ISAC-3 no doubt will add a few of its own. For instance, the chemical industry, probably through ISAC-3, will push for exceptions lists. Such lists will contain import-sensitive products that chemical producers feel should be exempted from tariff cuts. In the past, many U.S. chemical companies have nominated products for exceptions lists. No doubt those same products will crop up again as candidates for exemption.

Meanwhile, many U.S. companies say they don't want to see chemicals "sacrificed on the altar of free trade," as one company official puts it. They do not want U.S. negotiators to reduce or eliminate tariffs on Canadian chemicals in exchange for Canadian concessions that will benefit another, nonchemical U.S. industry. Chemical industry trade experts with sharp memories recall that it has happened in past trade negotiations. They don't want to see it happen again.

Until now, most of the industry's efforts have been directed toward the Administration's trade officials. Industry spokesmen haven't bothered much with Congress because they haven't had to. But that will change soon. President Reagan notified the House Ways & Means Committee and the Senate Finance Committee on Dec. 10 that he intended to enter negotiations with Canada. Under a "fast-track" approach, Congress has 60 working days in which to consider the proposal. If Congress doesn't act, negotiations are automatically approved.

Trade observers think that Congress will give the green light to the trade talks, despite some Congressional apprehension about Canadian subsidies on lumber and a few other issues. It's likely, however, that the two committees will hold hearings.

That's when the chemical industry's trade experts will really roll up their sleeves. With the U.S. trade deficit at an all-time high, Congressional ears are sensitive to talk about trade balances. Chemical industry witnesses will point out that, although the U.S. industry still enjoys a positive balance of trade, its trade surplus has been dwindling rapidly. In 1980, the U.S. chemical industry had a $12.1 billion trade surplus. Last year, that surplus had shrunk to $7.7 billion.

Canada is the U.S.'s largest chemical trading partner, just as it is the U.S.'s largest partner in overall trade. The U.S. shipped $2.8 billion worth of chemicals into Canada last year and imported $3 billion in chemicals from there. That means that the U.S. had a $200 million deficit in its chemical trade with Canada. In fact, the U.S. chemical trade balance with Canada has been in the red every year except 1983 for the past eight years.

That deficit makes the prospect for free trade between the two countries an important issue for the U.S. chemical industry. Usually vocal industry spokesmen have been quiet so far—only because there has been little specific to talk about. As Congressional hearings get under way and negotiators in both countries clarify their objectives and strategies, that will change.

Many U.S. chemical companies have expressed their views about Canadian-U.S. free trade in the past. Those views haven't changed. Typically, most companies want some of their products exempted from tariff cuts. Monsanto, among others, for instance, doesn't want duty-free

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treatment given to styrene, polystyrene, and a few other products, including formaldehyde, maleic anhydride, and 2-ethyl hexanol. Other companies suggest for exemption such bulk chemicals as polyethylene, methanol, polyvinyl chloride, ethylene oxide, and ethylene glycol.

Allied-Signal also is concerned about polyethylene, but not so much as about Canada's uranium policy. Canada requires that all uranium concentrate be converted to uranium hexafluoride before it's exported. The only converter in Canada is Eldorado Nuclear Ltd., which is a subsidized national corporation.

Allied-Signal is one of only two private uranium converters in the U.S. The other is Kerr-McGee. But Canada's policy, says Allied-Signal, means that Allied-Signal cannot compete for the business of converting Canadian uranium.

On the other hand, some companies support free trade with Canada simply on principle. They range from large companies such as Dow Chemical to the relatively small ones such as Huntsman Chemical, Salt Lake City. Dow, which has a subsidiary in Canada, supports U.S.-Canada free trade as long as energy and investment policies are harmonized between the two countries and the negotiations are broad-based, rather than sectoral. Jon Huntsman, chairman and president of Huntsman Chemical, favors free trade because "protectionism only accelerates the decline of key industries." He feels that way even though his company will receive styrene from American Hoechst under a tolling agreement that makes styrene from Canada less attractive to the company.

No doubt company positions will be revised and refined as negotiations near. One factor that companies will have to pump into their equations is the impact of the recent drop in crude oil prices. How they evaluate it could help to define how they feel about the relative competitive position of the Canadian chemical industry. Several companies admit to going through the "number crunching" right now.

The drastically lower oil prices already have had an impact on Frederick Knight's thinking. Knight, a senior vice president for Borg-Warner Chemicals, opposed making tariff cuts on styrene under any Canadian-U.S. trade agreement. His reason is Canadian energy pricing policies that help to support production of styrene raw materials from tar sands in Alberta. He still opposes tariff cuts on styrene, but for a different reason. He is afraid that the U.S. government will take advantage of the recent oil price cuts and push through an oil import fee to raise deficit-reducing revenue. If that happens, Knight says, all they'd be doing is substituting a U.S. disadvantage south of the border for what used to be a Canadian advantage north of the border. ☐

CHEMISTRY AS A LIFE SCIENCE SYMPOSIUM-III

The third in this series of biennial symposia will be held at the
ROBESON CENTER
RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY, NEWARK
FRIDAY, 21ST MARCH, 1986
Symposium to be chaired by Prof. Albert I. Meyers, Colorado State Univ.
PROGRAM

- **Welcome and Opening Remarks** 9:00 A.M.
- **"Dimensional Tolerance of Watson-Crick DNA, RNA Cross-Sections: A Synthetic Approach"** 9:15 A.M.
  Professor Nelson J. Leonard
- **Coffee Social** 10:15 A.M.
- **"Manipulation of the Arachidonic Acid Cascade"** 10:45 A.M.
  Sir John R. Vane, FRS, 1982 Nobel Laureate for Physiology or Medicine; Keynote Address
- **Lunch** 11:45 A.M.
- **"Mechanisms of Coenzyme B_{12}—Dependent Rearrangements"** 1:30 P.M.
  Professor Jack Halpern
- **Coffee Social** 2:30 P.M.
- **"Molecular Recognition: Studies of the Binding of Oligosaccharides by Monoclonal Antibodies and Lectins"** 3:00 P.M.
  Professor Raymond U. Lemieux
- **"New Synthetic Technology and Natural Products Synthesis"** 4:00 P.M.
  Professor Kyriacos C. Nicolaou
- **Wine and Cheese Social** 5:00 P.M.

The symposium is free and open to the public, but advance registration is required because of limited seating capacity (600).

The symposium sponsors include: North Jersey Section of the ACS, Anaquest, Berlex Laboratories, Inc., CIBA-GEIGY Corp., Hoechst-Roussel Pharmaceuticals, Inc., Hoffmann-La Roche, Inc., Merck & Co., Inc., Ortho Pharmaceutical Corp., Sandoz, Inc., Schering-Plough Corp., E.R. Squibb & Sons, Inc., and Rutgers, the State University of New Jersey, Newark.

Symposium Organizing Committee: Michael Czarniecki, Michael J. Green, Stan S. Hall, Faizu Kathawala, Dennis Keith, John J. Partridge, H. Burt Renfroe.

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Note: Advance registrations will be acknowledged and accepted in order of their receipt, to within the capacity of the available space.

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Reagan proposes increasing federal R&D funding 16% next year
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FEBRUARY 17, 1986

CHEMICAL & ENGINEERING NEWS

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Slow but solid growth
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CHEMICAL & ENGINEERING
NEWS

Volume 64, Number 7
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FEBRUARY 17, 1986

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- **Efforts of human rights activists, U.S. and European scientists rewarded by release of computer scientist Anatoly Scharansky from the Soviet Union.** Page 7
- **Du Pont will spend only $1.12 billion on R&D this year, 4% below the 1985 level.** Page 7
- **Chemical industry executives and Senators from northeastern states oppose tax on imported oil proposed as method of reducing federal budget deficit.** Page 8
- **Ban on chemical weapons nudges closer to reality as U.S. and Soviet actions indicate shifts in approach to meet that goal.** Page 8

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Process catalysts, used in petroleum refining and in chemical processes, are a steadily growing business in the U.S. **Page 27**

Funds for R&D Are Up 17% in Administration's Budget Proposal

Department of Defense R&D budget consumes large percentage, just under 70%, of total R&D budget; proposed funding for overall basic research is up 8%, whereas that for applied research is down 2%

Janice R. Long, David J. Hanson,
and Wil Lepkowski, C&EN Washington

According to acting Presidential Science Adviser John P. McTague, the proposed 1987 budget that the Administration sent to Capitol Hill on Feb. 5 "reflects three guiding priorities: to stop signing our children's names to IOUs for our own pocket money; to ensure a stable, secure nation and world by continuing to modernize our defensive forces; and to provide the scientific, technical, and human resource base to maintain the nation's leadership in an increasingly competitive marketplace."

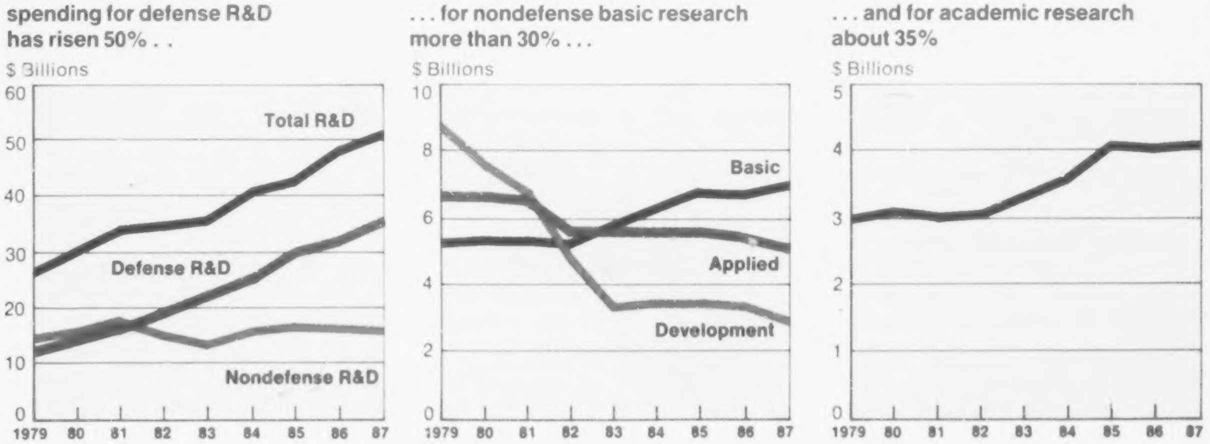
The two last priorities are accurately reflected in the proposed 1987 federal R&D budget, as is the Administration's commitment to basic research as opposed to applied research and development work. In an overall federal budget that is up only 1% from 1986 to $994 billion, R&D obligations are up 17%, or $8.8 billion, to $60.8 billion, and outlays are up 7%, or $3.6 billion, to $51.4 billion.

Those figures do not include funds for R&D facilities, which, if factored in, result in a 1987 increase in R&D obligations of 16% over 1986 funding levels to $62.5 billion. Overall obligations for R&D facilities are down 4% to $1.7 billion, and outlays are up 2% to the same figure.

Obligations for basic research are going in the opposite direction, up 8%, or $615 million, to $8.6 million. Outlays for basic research are up 5%, or $364 million to $8.3 billion. Obligations for applied research are down 2%, or $141 million, to $5.5 billion, and obligations for development are down 10%, or $347 million, to $3.2 billion.

Since the Reagan Administration took office in 1981, funding for federally sponsored development work

Under the Reagan Administration,



Note: Outlays. **Source**: Office of Management & Budget

Note: Obligations in constant 1985 dollars. **Source**: Office of Science & Technology Policy has dropped some 44%, and funding for applied research has dropped 8% in terms of constant 1985 dollars. Funding for basic research, on the other hand, has risen 30%, with the share going to colleges and universities rising 18% to some $6.4 billion in fiscal 1987.

The Department of Defense budget for research, development, testing, and engineering is consuming an ever larger percentage of the federal R&D budget. In 1986 it accounts for just under 65% of total R&D obligations, in 1987 just under 70%, according to Office of Management & Budget calculations. (R&D numbers obtained from individual agencies frequently differ from those used by OMB in preparing its analyses, known as Special Analysis, of total federal R&D funding.)

DOD's proposed RDT&E budget for 1987 is $41.9 billion, for an increase of $6.4 billion, or 18%, above the level funded in 1986. Most of that money does not support what is traditionally called research and development, but rather the testing of advanced tactical weapons systems and other engineering tasks. The portion of the budget that funds basic research, referred to as the technology base, is comparatively small. At slightly less than $3.6 billion, it represents less than 9% of the total RDT&E budget.

Quite a bit of that research money would be devoted to the Strategic Defense Initiative, the so-called Star Wars program, for defense against nuclear attack. Overall funding for SDI is proposed to increase to $4.8 billion for 1987, up from $2.75 billion obligated for 1986. (For the impact this growing source of funds has on universities, see story on page 23.) The SDI program began in 1985 with about $1.5 billion and so has grown about 300% in three years.

In other programs, the military services plan to double their spending at universities for graduate scholarships and assistantships, proposing about $50 million for 1987. This initiative was started just last year, and DOD proposes another doubling of funds for it in fiscal 1988. Total research support from DOD to universities will top $1 billion for the first time in 1987, and more than half of that will go to basic research. However, with the emphasis on technology development, it is estimated that only about $85 million will be for basic research in chemistry.

Among the big money items touted by Defense officials at the opening rounds of budget hearings is development of the JVX tilt-rotor aircraft, which is designed for rapid troop transport, and development of a new, faster, quieter attack submarine with an advanced combat system. Work on the MX, or Peacekeeper, missile continues with development support for the second 50 of these multiple-warhead missiles. Chemical weapons continue to be pushed by the Joint Chiefs of Staff, and new funds are requested for work on these.

In contrast to the skyrocketing defense RDT&E funding, the Administration once again is proposing a decrease in R&D support for the Department of Health & Human Services, down 1% to $5.47 billion. Virtually all the loss would come from the National Institutes of Health, which is scheduled to receive a cut of $478 million, or 9%, to $4.9 billion.

The Administration has made a careful study of what it wants from NIH, particularly after the battle it lost with Congress last year over the appropriate number of new and competing research grants. Congress passed a budget to fund 6500 such grants each year that was vetoed by the President. Congress compromised and overrode the veto, allowing NIH to increase its funding from about 5000 to 6000 new grants yearly.

HHS proposes in the 1987 budget that NIH fund 18,000 total grants, not just new grants, each year from a total of $2.8 billion. The average award would be $156,700, an increase of 2% over 1986. At present total grants may number about 18,300. HHS says that the new method of funding would provide more stability to the grants process and that NIH will be able to be more cost conscious in the review and approval of grants. To provide for a smooth transition to the 18,000-grant total, the Administration has sent a number of rescission proposals to Congress asking that some $23 million be deleted from NIH's fiscal 1986 budget.

One area where HHS hopes to find some savings is indirect costs. The Administration is proposing a 20% limit on administrative overhead for research projects, a move expected to save $86 million in 1987. The current average indirect cost levied on grants is 26%, according to the HHS Office of the Inspector General.

In other areas of HHS-sponsored R&D, the Food & Drug Administration would get an increase of $40 million to $424 million in fiscal 1987. Likewise, the proposed budget for the Centers for Disease Control is up $13 million to $380 million next year. The Administration is also proposing a smaller increase, $11 million, to go to the Alcohol, Drug Abuse & Mental Health Administration, raising its total to $928 million.

The Department of Energy remains the third largest federal funder of R&D, resulting from a sharp rise in

Glossary of budget terms

Fiscal year. Year running from Oct. 1 to Sept. 30. The fiscal year is designated by the calendar year in which it ends.

Obligations. Commitments made by federal agencies to pay out money for products, services, or other purposes, as distinct from the actual payment.

Outlays. Payments for obligations incurred under Congressionally granted budget authority generally made by issuance of checks on the Treasury. Outlays during any fiscal year may be for obligations incurred in previous fiscal years or in the same fiscal year.

Rescission. Enacted legislation canceling budget authority previously granted by Congress. Rescissions proposed by the President must be approved by Congress within 45 days to become effective.

Federal R&D funding would rise 17% overall . . .

$ Millions	Obligations 1987^a	Obligations 1986^a	Obligations 1985^b	Outlays 1987^a	Outlays 1986^a	Outlays 1985^b
Defense	$41,823	$33,485	$31,099	$32,693	$29,267	$27,878
HHS	5,471	5,524	5,444	5,532	5,561	4,997
Energy	4,886	4,785	4,901	4,819	4,778	4,900
NASA	4,051	3,594	3,235	3,743	3,528	2,970
NSF	1,508	1,334	1,346	1,455	1,338	1,186
Agriculture	907	922	941	911	913	689
Interior	345	381	389	351	403	414
EPA	310	334	320	332	318	275
Commerce	297	380	399	311	383	373
Transportation	277	364	430	331	416	417
Agency for International Development	203	206	210	209	208	204
Veterans Administration	194	186	227	187	182	215
All other	531	531	550	544	538	527
TOTAL	**$60,803**	**$52,026**	**$49,491**	**$51,418**	**$47,833**	**$45,245**

a Estimate. b Actual. **Note:** Facilities funding not included.
Source: Office of Management & Budget

. . . with basic research funding up 8% . . .

$ Millions	Obligations 1987^a	Obligations 1986^a	Obligations 1985^b	Outlays 1987^a	Outlays 1986^a	Outlays 1985^b
HHS	$3353	$3290	$3229	$3381	$3303	$2954
NSF	1423	1256	1262	1372	1260	1111
NASA	1085	857	728	1018	870	705
Energy	1045	922	926	1018	907	896
Defense	987	940	860	759	834	705
Agriculture	434	434	447	427	423	406
Interior	118	132	131	121	145	142
Smithsonian Institution	79	71	71	73	66	61
EPA	37	39	39	38	36	25
Commerce	20	22	23	20	21	23
Veterans Administration	16	15	15	15	15	16
Education	10	11	12	11	6	6
All other	25	28	27	27	30	26
TOTAL	**$8632**	**$8017**	**$7770**	**$8280**	**$7916**	**$7075**

a Estimate. b Actual. **Source:** Office of Management & Budget

. . . and funds for facilities down 4%

$ Millions	Obligations 1987^a	Obligations 1986^a	Obligations 1985^b	Outlays 1987^a	Outlays 1986^a	Outlays 1985^b
Energy	$ 759	$ 813	$ 909	$ 826	$ 902	$ 958
Defense	453	437	533	376	325	404
NASA	332	279	268	310	271	247
NSF	84	68	74	81	68	64
Agriculture	42	92	41	69	48	34
HHS	10	54	43	27	46	43
All other	54	68	27	41	30	34
TOTAL	**$1734**	**$1811**	**$1895**	**$1730**	**$1690**	**$1784**

a Estimate. b Actual. **Source:** Office of Management & Budget

its defense-oriented research activities. Overall, DOE's R&D obligations would rise 3%, or $155 million, to $5.3 billion in fiscal 1987. Its defense R&D activities are slated to rise 19%, or $429 million, to $2.7 billion. That leaves civilian research programs with a 10%, $275 million decrease to $2.6 million.

Despite the overall decline, there are some bright spots in DOE's civilian research program. Funding for supporting research and technical analysis would increase 6% to $551 million. Within that total, operating expenses for the chemical sciences program, which were down slightly in fiscal 1986 because of the automatic Gramm-Rudman-Hollings deficit reduction law cuts, are up 11% to $86.4 million. The program's capital equipment budget would rise 12% to $9.6 million, whereas the construction budget would decrease 3% to $5.4 million.

The operating budget for materials sciences research is slated to increase 17% to $157 million. The capital equipment budget would rise 29% to $15.5 million, but the construction budget would fall 44% to $23.9 million. In other areas, university research support would rise 7% to $11 million; however, funding for university research instrumentation would fall 21% to $5 million.

Sliding very steeply is DOE's fossil energy R&D budget, down 56% to $150 million. Within that program, funding for coal R&D, which includes a fair amount of chemical research, would fall even further—67% to $82.2 million. Proposed funding for conservation R&D is down 54% to $71.2 million, solar R&D down 47% to $92 million, and nuclear energy programs are down 12% to $333 million. Within the last category, however, funding for one program—space and defense power systems—would increase a dramatic 250% to $71.7 million. The program focuses on developing nuclear power sources to support emerging DOD requirements for a variety of terrestrial and space missions, including SDI.

Exactly what will happen at the National Aeronautics & Space Administration is a mystery. Following the tragic loss of the space shuttle *Challenger*, the acting NASA administrator has vowed no more shuttles will be launched until their safety is assured. What that will do to shuttle expenses, now the greatest part of the NASA budget at about $3.1 billion for its launches and communications controls, cannot be guessed. Acting NASA Administrator William R. Graham says the shuttle will continue to be the U.S.'s principal space transportation system.

R&D spending for NASA is slated at $3 billion for 1987, a 9% increase that is somewhat better than the 3% overall increase NASA is requesting. The R&D funds will go toward initiation of space station development, with $410 million spent to complete initial design work. Funds also will go to a new aerospace plane technology program. A major new program, one of the very few to be proposed in recent years, is Topex. Nearly $30 million will support this ocean topography experiment, to be conducted jointly with France. To be launched in 1991, it will be a satellite system that gives oceanographers the first opportunity to observe currents on a global scale.

Defense items boost DOE research budget

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986–87
Weapons R&D, testing	$2101.2	$1729.8	$1640.8	21%
Energy supply R&D	1599.5	1693.5	1818.8	−6
Supporting research and technical analysis	551.9	519.7	516.0	6
Magnetic fusion	333.0	365.4	429.5	−9
Nuclear energy	332.7	377.4	392.5	−12
Environment	273.8	228.6	230.5	20
Solar and other renewables	91.9	173.6	210.2	−47
Electric energy systems and storage	16.2	28.8	40.1	−44
General science and research	773.4	681.4	721.8	17
Naval reactors development	593.6	535.7	500.4	11
Fossil energy R&D	150.1	343.0	337.1	−56
Conservation R&D	71.2	170.9	151.6	−54
TOTAL	$5289.0	$5134.3	$5170.5	3%

a Estimate. b Actual. Source: Department of Energy, S. Rept. 99–110

NSF's total budget is up 8% . . .

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986–87
Mathematical and physical sciences	$ 449.3	$ 410.0	$ 397.2	10%
Astronomical, atmospheric, earth, and ocean sciences	383.2	362.6	353.0	6
Biological, behavioral, and social sciences	282.4	260.1	253.5	9
Engineering	185.5	162.5	150.6	14
Antarctic program	117.0	115.2	110.8	2
Science and engineering education	89.0	87.0	82.0	2
Program development and management	78.0	72.5	72.0	8
Advanced scientific computing	53.6	45.2	41.4	19
Scientific, technological, and international affairs	47.0	39.5	43.7	19
Special foreign currency	0.7	1.0	2.8	−30
TOTAL	$1685.7	$1555.6	$1507.0	8%

a Estimate. b Actual. Source: National Science Foundation

. . . as is funding for the sciences . . .

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986–87
Ocean sciences	$ 133.6	$ 124.1	$121.3	10%
Physics	126.6	118.6	115.8	7
Materials research	117.4	109.7	107.0	7
Chemistry	101.0	89.8	87.6	13
Atmospheric sciences	100.6	96.8	95.0	4
Astronomical sciences	85.1	84.2	82.8	1
Molecular biology	67.1	62.0	60.9	8
Biotic systems and resources	66.5	61.0	58.1	9
Mathematical sciences	59.8	51.7	47.7	16
Cellular biology	56.6	52.1	52.4	9
Earth sciences	55.0	49.0	45.9	12
Behavioral, neural sciences	48.9	45.7	44.4	7
Computer research	44.5	40.2	39.1	11
Social and economic sciences	31.4	30.0	28.8	5
Information and science technology	11.9	9.3	8.9	28
TOTAL	$1108.0	$1024.2	$995.7	8%

a Estimate. b Actual. Source: National Science Foundation

. . . and for chemical programs

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986–87
Chemistry	$101.0	$ 89.9	$ 87.6	13%
Chemical dynamics	17.6	16.0	15.5	10
Structural chemistry and thermodynamics	17.1	15.5	15.0	10
Chemical physics	16.6	14.9	14.4	11
Chemical instrumentation	14.1	11.6	11.6	22
Chemical analysis	12.5	11.3	11.1	11
Synthetic organic, natural products chemistry	12.3	10.9	10.6	13
Synthetic inorganic, organometallic chemistry	10.6	9.5	9.3	12
Materials research	57.4	55.8	55.9	3
Laboratories	27.7	27.2	27.1	2
Solid-state chemistry	9.1	8.7	8.2	5
Polymers	7.5	7.1	7.6	6
Ceramics and electronic materials	6.9	6.6	6.5	5
Instrumentation	6.2	6.2	6.5	—
Chemical, biochemical, and thermal engineering	30.1	29.1	29.1	3
Thermal systems	9.0	8.5	8.8	6
Thermodynamics, transport phenomena	4.7	4.6	4.5	2
Process and reaction engineering	3.7	3.4	3.5	9
Multiphase, interfacial phenomena	3.6	3.4	3.3	6
Kinetics and catalysis engineering	3.3	3.1	3.0	6
Separation and purification processes	3.2	3.1	2.9	3
Biochemical and biomass engineering	2.6	3.0	3.1	−13
Biochemistry	16.1	15.1	14.0	7
Chemical oceanography	13.3	12.6	12.4	6
Geochemistry	10.0	9.7	9.7	3
Atmospheric chemistry	9.2	7.3	7.1	26
TOTAL	$237.1	$219.5	$215.8	8%

a Estimate. b Actual. Source: National Science Foundation

Administration still trying to cut NIH budget

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986–87
National Institutes	$4589.6	$4987.1	$4720.9	−8%
Cancer	1158.1	1252.7	1186.8	−8
Heart, Lung & Blood	785.7	859.2	805.3	−9
General Medical Sciences	471.5	514.8	482.3	−8
Diabetes & Digestive & Kidney Diseases	419.0[c]	569.3	543.6	−26
Neurological & Communicative Disorders & Stroke	399.4	433.4	396.9	−8
Allergy & Infectious Diseases	330.6	383.5	371.0	−14
Child Health & Human Development	309.1	321.8	313.3	−4
Environmental Health Sciences	188.0	197.5	194.8	−5
Eye	179.2	195.1	181.7	−8
Aging	145.8	156.5	144.5	−7
Arthritis & Musculoskeletal & Skin Diseases	106.7	—	—	
Dental Research	96.5	103.3	100.7	−7
Research resources	234.2	305.7	304.0	−23
National Library of Medicine	56.4	57.8	55.9	−2
John E. Fogarty Center	11.3	11.6	11.7	−3
Research facilities	8.0	14.9	21.7	−46
TOTAL	$4899.5	$5377.1	$5114.2	−9%

a Estimate. b Actual. c Funding is low because of new institute for arthritis. Source: Office of Management & Budget

Defense research posts another big gain

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986-87
Tactical programs	$12,671.5	$10,901.0	$ 9,062.2	16%
Strategic programs	9,429.6	8,054.4	8,169.0	17
Advanced technology development	6,574.7	4,234.3	2,750.6	55
Intelligence and communications	5,102.9	4,703.4	3,953.0	9
Program management and support	4,566.0	4,124.5	3,814.0	11
Technology base	3,585.3	3,449.0	3,120.7	4
TOTAL	**$41,930.0**	**$35,475.6**	**$30,869.5**	**18%**

a Estimate. b Actual. **Source:** Department of Defense

Agricultural research is down slightly

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986-87
Agricultural Research Service	$515.0	$486.2	$516.6	6%
Cooperative State Research Service	246.3	278.9	304.3	−12
Forest Service research	111.5	120.1	121.7	−7
National Agricultural Library	11.4	10.8	11.4	6
TOTAL	**$884.2**	**$896.0**	**$954.0**	**−1%**

a Estimate. b Actual. **Source:** Department of Agriculture

Big loss for EPA research wipes out '86 gains

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986-87
Air	$ 63.2	$ 68.4	$ 66.4	−7%
Energy/acid rain	59.6	59.1	56.8	1
Hazardous waste	50.6	51.8	46.6	−2
Toxic substances	32.4	34.9	25.0	−7
Water quality	24.4	27.7	27.3	−12
Drinking water	22.5	24.2	23.3	−7
Interdisciplinary	19.4	24.6	26.6	−21
Pesticides	13.2	11.8	9.7	12
Management/support	9.7	9.3	9.5	4
Radiation	0.2	0.2	1.9	0
Superfund	c	12.6	12.4	—
TOTAL	**$295.2**	**$324.6**	**$305.5**	**−9%**

a Estimate. b Actual. c No Superfund R&D budget for 1987. **Source:** Environmental Protection Agency

NASA's R&D funding continues to climb

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986-87
Conduct of R&D	**$3003.1**	**$2756.8**	**$2468.1**	**9%**
Physics and astronomy	539.4	607.1	677.2	−11
Space applications	526.6	518.7	374.1	2
Space transportation	465.5	437.0	391.4	7
Space station	410.0	205.0	155.5	100
Aeronautical research	376.0	354.0	342.4	6
Planetary exploration	323.3	352.8	290.9	−8
Space research & technology	180.2	168.0	150.0	7
Life sciences	74.7	69.9	62.3	7
Commercial programs	45.3	28.1	9.5	61
Transatmospheric research	45.0	—	—	—
Tracking & data acquisition	17.1	16.2	14.8	6
R&D facilities	**181.3**	**139.3**	**157.6**	**30**
TOTAL	**$3184.4**	**$2896.1**	**$2625.7**	**10%**

a Estimate. b Actual. **Source:** National Aeronautics & Space Administration

A number of major NASA programs have been cut back substantially in the 1987 proposal. Among them are the gamma-ray observatory, down 41% to $55 million; the Hubble space telescope program, down nearly 80% to $28 million; and the Venus radar mapper mission, down 47% to $67 million. However, there would be some large increases in the areas of data and research analysis and in the Mars observer project, which would get a funding increase of 66% to $63 million.

The total figure for federal nondefense R&D stays barely even; but the National Science Foundation's 1987 budget leaps a full 8%—from $1.56 billion to $1.69 billion. Even so, NSF director Erich Bloch insists the $130 million rise is "a modest increase, given the needs of the country."

Chemistry fares well in the proposal, with funding rising 13% to $101 million, and funding for the closely related field of materials research rising 7% to $117 million. The foundation's engineering research program continues to receive strong emphasis with a 14% jump to $186 million. Bloch isn't specific, but he says three to five more of the vaunted Engineering Research Centers would be funded in 1987. That comes somewhat as a surprise, since prebudget rumors held that no more than two would be funded.

Bloch points out that NSF is emphasizing four areas of growth in its 1987 plans:

- Biotechnology, funding for which rises from $86.5 million to $106.5 million and will include a series of large and small centers of specialty.
- Computational science and engineering, funding for which rises from $57 million to $84 million, to build upon the supercomputer revolution sweeping basic science and engineering today.
- Global geosciences, funding for which increases from $17.6 million to $35.6 million, as part of an interagency push to understand natural disasters better and to study the impact of technology on natural processes.
- "Broadening participation in science and engineering research and education" to further bring women and minorities into the scientific mainstream and beef up the scientific capabilities of small colleges.

No new supercomputer centers will be established, Bloch says, but the $54 million budgeted for advanced scientific computing will go toward linking up computer facilities of all types and maintaining the five big centers that already are being established with funds from the current fiscal 1986 budget.

He adds that support for instrumentation and facilities will be increased across the board. "In chemistry, increased support for shared instrumentation will be provided," he says. Broken out as a line item for the first time in this year's budget proposal, funding for chemical instrumentation is up 22% to $14.1 million.

For the Department of Agriculture, the Administration request is less than 1% below the 1986 budget, after the deficit reduction cuts are made. Funding for USDA's primary research organization, the Agricultural Research Service, would increase $29 million to

$515 million. The increase would provide additional funds for research into new food and more nonfood uses of agricultural products. More than $3 million would go to research on plant germplasm, which follows a recent move to put more emphasis on biotechnology in agriculture.

The Cooperative State Research Service, which manages funds for research at state agricultural experiment stations and other institutions, would get a 12% funding cut. That comes on top of the 1986 Gramm-Rudman-Hollings reductions. About the only good news for the office's programs is a $6.7 million increase in funding for the experiment stations and $1 million more for the predominately black colleges set up in 1890 and Tuskegee Institute. The special research grants program and the animal health and disease program are to be eliminated. In addition, two training grant programs, the Morrill-Nelson and the Competitive Graduate Training Grants, are to be cut drastically or eliminated because the Administration believes they are not needed.

Forest research would be trimmed nearly 7% to $112 million in 1987. USDA says two programs, a $6.5 million competitive grants program and an acid precipitation survey, account for the drop.

Also on the down side is the Department of Interior's R&D budget, down 10%, or $36 million, to $345 million. The budget for the Geological Survey, which accounts for about 90% of Interior's R&D funding, would decline $14 million to $204 million. The Bureau of Mines' R&D budget would drop $22 million to $61 million. The Administration is proposing to eliminate the federal contribution to the mineral institutes, which support minerals research and engineering programs, at 31 colleges and universities. Research obligations for the Fish & Wildlife Service, which among other things studies the impact of broad-scale environmental changes on fish and wildlife populations and habitat, would be held essentially constant at $49 million.

The Administration proposes a fairly drastic reduction of 28% in the Department of Commerce's R&D programs. At the National Oceanic & Atmospheric Administration, R&D obligations would decrease 25% from 1986 to $192 million. According to OMB, the Administration wants to do away with "lower-priority" research in such programs as Seafloor Spreading Center Research, National Underseas Research Program, National Sea Grant College Program, and some programs of the National Marine Fisheries Service. A 1986 rescission proposal of $28.9 million in the Sea Grant program accompanied the new budget to Capitol Hill. However, NOAA is expected to increase its research on radiatively important trace species and hurricane predictions, while maintaining its acid rain research program.

The proposed overall budget for the National Bureau of Standards is down just 3%, or $5 million, to $121.8 million. However, its operating budget, which supports its research activities, would decline 10%, or $12 million, to $111.3 million. The budget includes funds for construction of the new cold neutron research facility used for materials science. However, for what seems like the umpteenth year in a row, the Administration is proposing to do away with the Center for Fire Research and the Center for Building Technology. This year it has added the technical competence program, the computer sciences and technology program, and the research associates program to the list of programs to be eliminated or reduced.

The R&D budget at the Environmental Protection Agency is one of the smallest in the federal government, but because its results are a base for all-encompassing regulations, it is watched carefully. For 1987, the Administration is proposing a 9% decrease in EPA's R&D budget to $295 million. Major cuts are planned in the areas of water quality, down 12%, and interdisciplinary research, down 21%. It is mainly exploratory research—that is, research not tagged to specific problems—that is being cut.

Another reason for the drop is the loss of the Superfund research program. Because Congress has not yet passed a reauthorization bill for Superfund, the Administration has made no R&D request for it. If one were there, something in the range of $13 million might be proposed. A research program is included in the bill now being considered by a House-Senate conference committee. Extramural research contracts under Superfund are starting to expire, and that is one of the reasons EPA Administrator Lee Thomas has asked for interim Superfund money.

The only program areas with some increase in support are acid rain, still a problem looking for a solution; and pesticide research, which is being expanded to accommodate more recombinant DNA and ecological studies.

The agency says that expanded cross-media research is being supported, and it mentions the problem of air emissions from uncontrolled hazardous waste dumps as an area needing more attention. Two other areas mentioned are research to support the new air toxics strategy and work to get a better determination of pesticide contamination of groundwater.

In another area, one program that was scheduled for elimination in the 1986 budget request—Tennessee Valley Authority's fertilizer development center in Muscle Shoals, Ala.—is alive, if not exuberantly healthy, in the 1987 budget request. That facility's budget would decline 16% to $48.5 million. And the Administration intends for the facility's technology development work to become self-supporting in 1987.

In the years before Gramm-Rudman-Hollings, the Reagan budget proposals could pretty much be viewed as a floor through which the R&D budget would not fall. When the Administration asked for decreases in the NIH budget, or the fossil energy R&D program, or EPA's R&D budget, the Congressional response was to at least increase the request. The one exception has been the DOD R&D budget, for which Congress has normally cut back what would have been very large increases. That pattern may well hold true again this year. R&D makes up such a small part of the total federal budget, just 6%, that cutting it drastically isn't going to result in any noticeable savings. □

Natural Gas-Based Chemicals Pressured by Imports

Operating rates sag as imports of ammonia, urea, and methanol from countries with lower-cost feedstocks continue to increase

Bruce F. Greek, C&EN Houston

In spite of lower production costs resulting from declining natural gas prices, producers of ammonia, urea, and methanol expect to fill a smaller part of total U.S. demand this year and for the rest of this decade. Makers of these natural gas-based chemicals are joining the ranks of some other manufacturers, such as the auto and textile industries, whose plant operating rates are sagging although demand is holding.

Demand for ammonia and urea is forecast to decline slightly this year because of farm economic woes. However, demand is expected to decline less than production. Methanol's demand and production is expected to rise in 1986. However, output of none of these three will match demand, so imports will continue to play an important role. In the case of methanol, imports will account for more than 25% of supply.

The increase in imports of ammonia, urea, and methanol results in part from the lower prices offered by countries with lower feedstock (specifically methane) costs.

Key Chemicals

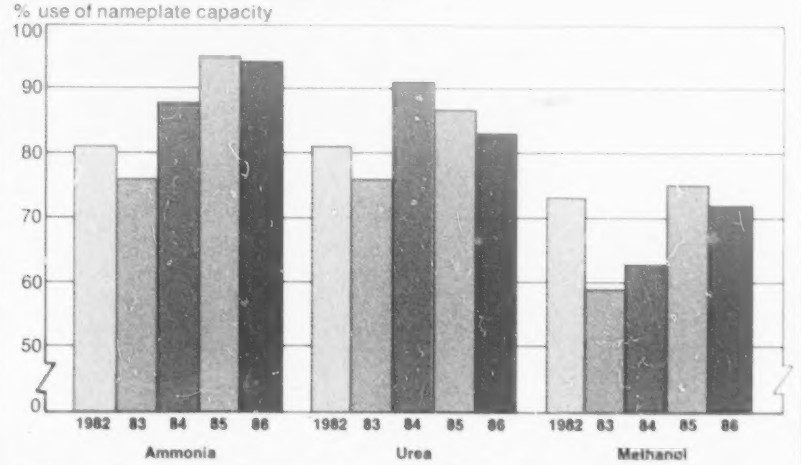
Some sizable quantities of these materials come from areas, including communist countries, where U.S. companies have no influence on production other than a willingness to bargain on purchase prices. This shift has occurred even as U.S. natural gas prices weakened slightly and then began to decline more steeply. The trend toward increasing imports is not expected to reverse anytime soon. Even with further reduction in U.S. natural gas prices, the differential between this country's gas costs and foreign gas costs in such areas as Canada and Trinidad will stay relatively large.

Significant imports of gas-based chemicals, accounting for an important part of U.S. demand, will continue for years even as domestic natural gas costs decline. Although those prices will decline less than have crude oil prices recently, they will continue to fall as market competition forces natural gas producers to reduce selling prices. Generally, industrial natural gas's major competitor is residual fuel oil. Both are used heavily in power generation, in addition to coal and nuclear fuel. Power plant operators have found it economically desirable to build in flexibility to use either natural gas or oil. During the past five years, this flexibility has been pursued widely. Therefore, as crude oil prices decline, pressure will continue on natural gas prices. As a result, about two thirds of cash production costs (made up of gas for feedstock and fuel) for ammonia and methanol will decline more rapidly than all other costs, including capitalization.

With lower natural gas prices, ammonia and methanol producers would temporarily enjoy lower costs, and possibly a respite from further loss of markets to importers whose costs for all but feedstock and fuel continue to rise. However, as the lower-cost gas is consumed over the next few years, these chemical producers may face declining supplies unless prices reverse their current trend.

For details of the near-term outlook for ammonia, urea, and methanol, please see the following pages.

Capacity use dropping this year



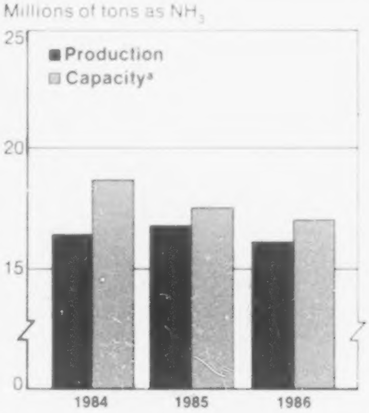
Sources: International Trade Commission, Census Bureau, C&EN estimates

Ammonia

NH_3

- ***Production to fall***
- ***Capacity down***
- ***Prices lower***

PRODUCTION/CAPACITY



a First quarter, some capacity idled.

MAJOR PRODUCERS

CF Industries, Chevron, Farmland, Union Oil, Williams Cos. (Agrico)

HOW MADE

Catalytic reaction of nitrogen from air and hydrogen from natural gas

MAJOR DERIVATIVES

Ammonium nitrate 20%, urea 20%, ammonium phosphates 15%

MAJOR END USES

Fertilizers 80%, fibers and plastics 10%, explosives 5%

FOREIGN TRADE

Exports—falling to about 500,000 tons, imports—falling to about 2.5 million tons

PRICES

About $110 per ton on Gulf Coast

U.S. production and consumption of ammonia almost certainly will fall in 1986. The key question is how much production will decline—and that could differ significantly from the expected decrease in consumption.

Current forecasts, in this early part of the fertilization and growing season, call for U.S. ammonia output to decrease only modestly to 16 million tons, about 4% less than 16.6 million tons estimated for 1985. That will account for less than 90% of anticipated consumption. The net of imports of ammonia over exports of some 2 million tons will supply nearly all the remainder of demand. Inventory changes are expected to be minimal in 1986.

Consumption of ammonia this year probably will exceed 18 million tons, with more than 80% going either directly as fertilizer or made into other forms of nitrogenous fertilizer, such as urea, ammonium nitrate, or diammonium phosphate. Large and unpredictable quantities of these other forms of nitrogen-containing fertilizers also will be exported. Sometimes in the past, direct exports of ammonia and exports of nitrogen fertilizers have accounted for nearly a quarter of ammonia consumption. On the basis of total change in ammonia equivalents, the net of exports less imports will be lower in 1986 than it was in 1985.

Total ammonia consumption expected in 1986 in the U.S. will be down more than will production, probably in the range of 6%, or about 1 million tons. Agricultural uses will be down even more, possibly as much as 10%, but more likely 8%, when the final results of reductions in crop acreage are determined. In 1986, exports of some nitrogen fertilizers could increase modestly as a result of a decline in the strength of the dollar and because of lower selling prices. Imports of ammonia and derivatives likely will decline as well, because lower selling prices for ammonia are expected to hold during most of the year.

Consumption of ammonia (as well as of other fertilizers) will depend on variables other than weather. For example, the financial condition of agriculture in general is worse than it has been in recent years. It's questionable whether 10 to 25% of farmers will be able to pay for or to get loans to buy fertilizer they need.

New farm legislation is attempting to make U.S. agricultural products more competitive in world markets. Farm crop support prices are expected to be lowered, but it is hoped that farm income will be maintained. That could loom large in fertilizer consumption.

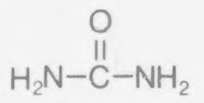
As part of the effort to reduce surpluses, various programs to reduce planted acreage have been proposed. Some of the proposals call for up to 90 million acres to be taken out of the total 340 million acres planted in 1985. Sources suggest that nearer 30 million acres will be left unplanted, which is less than a 10% reduction. Farmers likely will not plant the poorer land and will more heavily fertilize the better land to increase yields, suggesting a slightly improved use of plant nutrients per acre for 1986.

Nonagricultural uses of ammonia account for less than 20% of U.S. consumption. Such uses, the largest of which are in making intermediates for major-volume fibers such as acrylonitrile and nylons and as blasting agents, are barely growing.

Ammonia producers and importers will easily supply the 1986 demand except during the peak month of April, a month when a distribution problem regularly occurs. New ammonia capacity recently completed in Canada will supply material at prices competitive with the now reduced U.S. production costs. Additional U.S. ammonia capacity may be shut down, following the 1.5 million tons of capacity closed over the past two years. However, the U.S. ammonia industry has finally become very lean with the forecast average plant operating rate for 1986 at more than 90% of nameplate capacity.

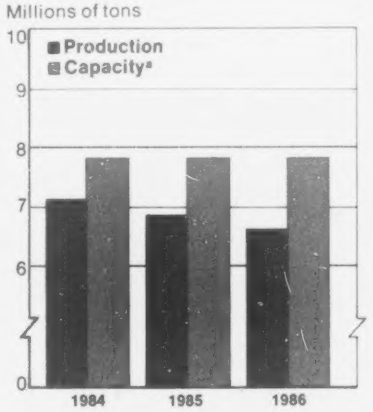
Key Chemicals

Urea


$H_2N-\overset{\overset{\displaystyle O}{\|}}{C}-NH_2$

- ***Production to slow***
- ***Capacity on hold***
- ***Prices weak***

PRODUCTION/CAPACITY



[a] First quarter.

MAJOR PRODUCERS

CF Industries, Farmland Industries, Triad, Unocal, Williams Cos. (Agrico)

HOW MADE

Reaction of ammonia and carbon dioxide under pressure

MAJOR DERIVATIVES

Urea-formaldehyde resins 5%

MAJOR END USES

Fertilizers 80%, animal feeds 10%, adhesives and plastics 5%

FOREIGN TRADE

Exports—falling below 1 million tons, imports—declining below 2 million tons

PRICES

About $100 per ton on Gulf Coast

Urea production outstripped forecasts in 1984 and 1985 because of strong U.S. demand. And it could surprise forecasters this year, too.

However, it's unlikely that strong demand for urea will push production this year above that in 1985. Present forecasts, made before the major consumption rush begins in April, are for a 4% decline from 1985 to 6.5 million tons. Production in 1985, estimated at more than 6.8 million tons, also was down from the previous year's 7.15 million tons, which was close to the all-time high of about 7.5 million tons in 1981.

There's no mystery why demand for urea is expected to be down this year—lower U.S. demand for nitrogenous fertilizers and animal feeds, smaller exports, and little, if any, change in demand for urea formaldehyde resins and other miscellaneous nonfarm uses. Imports of urea may increase slightly to reduce U.S. production, but current low selling prices and relatively high inventories will tend to hold down imports.

Total demand for urea of about 7.4 million tons in 1986 likely will exceed U.S. production about 750,000 tons. That amount will be met by a combination of imports from traditional suppliers such as Canada and Western Europe, from other sources such as the U.S.S.R. and Eastern Europe, and from the result of barter deals involving grain. Total demand will be down about 7.5% from the recent high of slightly more than 8 million tons a year.

In the U.S., agricultural demand for urea will be affected by weather and farming economics, but export demand also could upset forecasts. Some past major importers of urea such as China and India at times dropped out of the market in 1985, cutting U.S. exports drastically. Even with a decline in the value of the dollar, other countries—Indonesia for one—could capture a part of U.S. export markets as those countries bring on new capacity and seek to replace declining revenues from sale of petroleum and natural gas. Nevertheless, former large importers of U.S. urea could end up requiring more material than they can obtain from other countries, and again may buy U.S. product, resulting in low forecasts.

Weather and distribution limits might upset demand forecasts, because of a growing acceptance of solutions of urea and ammonium nitrate (UAN solutions) as a nitrogenous plant nutrient. If the weather is good in April and May when very large amounts of ammonia are applied to cornfields, local demand could exceed supplies available for immediate application. (Corn requires about 40% of nitrogen fertilizers in the U.S.)

Moreover, farmers might encounter delays in financing fertilizers at this time, resulting in a significant amount of cropland's receiving less nitrogen than desirable. To make up for this kind of deficiency, farmers could "side dress," which means apply UAN solution between the crop rows after corn is several inches high. In that case, the demand would surge a few months after normal fertilization time, raising consumption of urea unexpectedly high near the end of the fertilizer year.

Complex economics also enter into demand for urea. Currently, urea has two major price areas. High-quality, well-formed urea granules bring $100 to $110 per ton on the Gulf Coast. Dusty, off-grade urea (often imported material) sells for about $85 per ton. The high-quality material sells well because of the ease with which it can be made into solid mixed fertilizers. The dusty material will go to make UAN solutions, which, because of handling expenses, eventually will cost the user about the same as high-quality urea. If demand for UAN solutions for later side dressing is strong, then imports could rise, supplementing strained production plants late this spring and selling for better prices because all grades of urea might cost more.

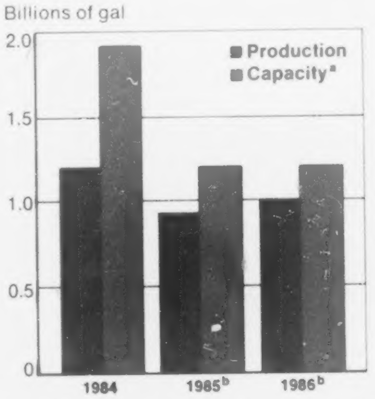
Key Chemicals

Methanol

CH_3OH

- ***Production down***
- ***Capacity in flux***
- ***Prices holding***

PRODUCTION/CAPACITY



a First quarter. b Additional 700-plus gal of capacity on standby

MAJOR PRODUCERS

Arco Chemical, Borden, Celanese, Du Pont, Texaco

HOW MADE

Reaction of carbon monoxide and hydrogen made by reforming natural gas (methane), and heavier hydrocarbons; gasification of coal

MAJOR DERIVATIVES

Formaldehye 30%, acetic acid 10%, chloromethanes 10%

MAJOR END USES

Polymers used as adhesives, fibers, and plastics 50%; fuels and fuel components 20%

FOREIGN TRADE

Exports—declining further to less than 10 million gal, imports—leveling off at about 400 million gal

PRICES

About 40 cents per gal in volume

Synthetic methanol production in the U.S. will grow significantly during 1986, and operating capacity will increase, but only temporarily. That outlook suggests that producers might have better business prospects now than they had in the past two years. About a third of U.S. capacity was shut down during that time, and imports soared to meet nearly a quarter of demand. Meanwhile, exports dwindled to almost nothing.

The recovery, however, remains relative. Plans for restarting shuttered capacity depend on the economics of the industry rather than upon those of a single plant. Consumption of methanol in the U.S. is expected to increase very little this year, if the economy remains near its present growth rate. Manufacturing costs and selling prices are trending downward, with still much concern about whether costs can continue dropping faster than prices.

Operating capacity is expected to shift some this year. Probably no later than early in the second quarter, Du Pont will have completed restarting its methanol unit at Beaumont, Tex. With a capacity of 250 million gal a year, the Beaumont unit will more than replace the 200 million gal of capacity at Deer Park, Tex., which Du Pont will close as part of its plan to end, by 1987, its Syngas Co. joint venture with the USI division of National Distillers & Chemicals.

Using residual fuel oil, the Syngas plant makes synthesis gas—carbon monoxide and hydrogen—from which Du Pont makes methanol and USI makes acetic acid. The Du Pont-USI agreement for ending the partnership calls for Du Pont to modify the synthesis gas plant so that USI can assume ownership and operation of it. Du Pont also will withdraw from methanol production at that plant, after shutting it down late in 1986.

If the startup of the Beaumont unit goes smoothly, Du Pont probably will be able to produce at least 150 million gal of methanol at the unit during 1986. This capacity startup will account for most of the estimated increase in total U.S. methanol production in 1986, an increase to more than 1 billion gal, about 10% more than in 1985.

As a result of Du Pont's startup, capacity at the beginning of 1987 will be close to that at the beginning of this year, unless other capacity changes occur this year as a result of oil and gas price declines that have already begun. For 1986, actual operating capacity to make methanol will total about 1.4 billion gal. Without other changes in capacity, with imports at no more than 400 million gal, and with demand totaling 1.4 billion gal, the average plant operating rate this year will be about the same as last year's, 70 to 75% of nameplate capacity.

At about 1.4 billion gal, methanol demand will be up only marginally from last year's, fitting the pattern of smaller and smaller growth rates in recent years. As in the past few years, much of the growth this year will come from two uses—fuels and acetic acid. If housing and commercial construction follows optimistic forecasts and holds at last year's rates or increases, then methanol's major use—in formaldehyde—will increase slightly. However, formaldehyde's share of consumption of methanol likely will decline again because of faster growth of other uses. Resins and resin intermediates account for about 90% of formaldehyde consumption, with the two big resins, urea- and phenol-formaldehydes, taking half the total. Most of the formaldehyde-related resins are mature products with relatively low growth prospects.

The faster growing area of methanol consumption currently remains the fuel uses. With phaseout of lead additives in gasoline nearly complete, supplies of high-octane blend stocks are strained, creating strong demand for methanol-*tert*-butyl alcohol blends and methyl-*tert*-butyl ether (MTBE). In 1986, the fuel and fuel additives uses of methanol will take more than 10% of consumption.

Shortage of water fluoridation chemicals developing

David Webber, New York

Danger signals are flashing for supplies of the chemicals most commonly used to fluoridate municipal drinking water. Suppliers and government experts consider a shortage of the compounds, which are key to municipal programs to reduce tooth decay through treatment of water supplies, to be imminent. Reason: the agricultural slump.

It might seem a long distance from corn belt woes to municipal water systems, but supply of fluoridation chemicals is entirely dependent on the farm economy. The three major fluoridation compounds—hydrofluosilicic acid (HFSA), sodium silicofluoride (SSF), and sodium fluoride—are largely by-products of phosphoric acid production. No one produces the fluoridation chemicals on purpose. But phosphoric acid production has essentially come to a halt since Christmas, because inventories of derivative fertilizer products are overabundant.

As a result, say fluoridation chemical distributors, supply of HFSA and SSF, the two most popular compounds, has slowed to a trickle. HFSA "has been in extremely short supply since December, and it is getting worse," says Richard J. Lucier of LCI, Clayton, Mo., one of the major suppliers of the fluoridation chemicals bought under contract by community water systems in the U.S. (Chemtech is another major distributor.) Lucier has notified customers that he will soon begin allocating deliveries.

Thomas G. Reeves, national fluoridation engineer at the Centers for Disease Control (CDC) outside Atlanta, confirms the supply problem. "Supplies are tight now in most places and, in a few incidences, have run out or are about to," he comments. Reports coming into CDC, the lead agency in the nation's water fluoridation effort, so far have pinpointed spot shortages in Baltimore, several communities in Ohio, and parts of Louisiana, according to Reeves. "It looks like we will have a shortage," he says.

Observers believe the current tightness will become a real shortage because there is little sign that the fertilizer industry is about to recover anytime soon. "Any pickup in production is very unlikely in the near future, given the demand outlook for fertilizer by U.S. agriculture during the current crop year and given the depressed state of the export market," remarks Donald N. Collins, a Fertilizer Institute spokesman. Last month, the European Economic Community, in retaliation for U.S. quotas on EEC steel exports to the U.S., imposed similar restrictions on exports of finished phosphate fertilizers from the U.S. to EEC countries. "Although the tonnage is not large, it's another dent in U.S. exports," Collins says.

Another negative is the nature of phosphate fertilizer use. Unlike nitrogen-based fertilizers, which must be applied each season, phosphate fertilizers are not so essential. Farmers can skip a few applications, and they did so last fall. There is little reason to expect that cash-strapped farmers will buy any more phosphate fertilizer this spring than they absolutely must.

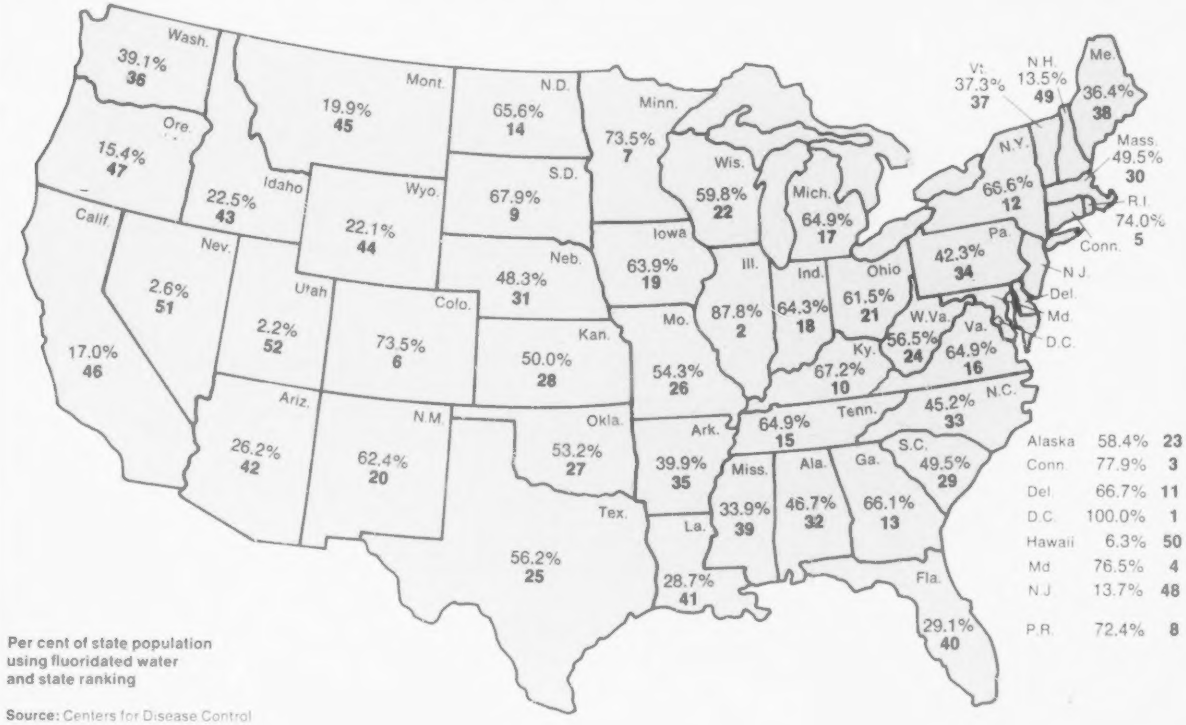
The difficulty in ensuring an unbroken adequacy of supply of the major water fluoridation chemicals stems not only from their being by-products, but because recovering and purifying them to water-treatment grade is not particularly lucrative. Collection units are expensive to buy, and they are expensive to maintain because of heavy scaling. The bulk of the HFSA recovered, for instance, is discharged into settling ponds or, when permitted, into local waterways. Very little was even recovered from stack gases before Environmental Protection Agency regulations began requiring it in the early 1970s.

It was air pollution control regulations, in fact, that resulted in bulk collection of HFSA, now by far the most commonly used fluoridation chemical. The reason is cost: HFSA sells to the biggest municipalities for about 4 cents per lb and to smaller communities for 15 to 20 cents per lb. By comparison, SSF sells for 25 to 30 cents per lb, and sodium fluoride for an average of 85 cents per lb, according to CDC's Reeves. It takes 46 lb of HFSA to bring 1 million gal of water to 1 ppm fluoride. Because the yield of fluoride ion per unit varies, it takes only 14 lb of SSF and 19 lb of sodium fluoride to accomplish the same task, Reeves explains. But HFSA is still the product of choice on price considerations: $1.84 for a large city to bring each 1 million gal to 1 ppm fluoride, compared to $3.85 for SSF and $16.15 for sodium fluoride.

Communities do not decide which compound to use solely on the basis of chemical cost, however. For one thing, HFSA is sold in solution (typically 25% acid to 75% water), requiring expensive solution metering pumps, storage tanks, and other bulk handling facilities. Communities with less money to spend often choose SSF, which can be added to the water supply through a dry feeder, still a big piece of equipment. Only the smallest systems, in general, use the expensive sodium fluoride, which can be administered via a saturator, the least costly equipment possible. Also, handling liquid HFSA can be hazardous, whereas SSF and sodium fluoride, as powders, are safer. That can be another key consideration to smaller communities that cannot afford extensive safety precautions.

What bothers people at CDC, the National Institutes of Health's National Institute of Dental Research, and other agencies about the current supply situation is that it is recurring. There was a two-month shortage in 1982 and several others in previous years. "What concerns me is the pattern of shortages," points out fluoridation expert Reeves. "They tend to come more closely together, and they tend to be more severe every time. If this one is more severe, it would continue that pattern." And there is good reason to expect the pattern to continue: At CDC urging, more communities are beginning to fluoridate their drinking water supply. Most of them use HFSA. Second, long-term trends, such as the decline of agricultural export markets and the rise of for-

Only 54% of U.S. population uses fluoridated water


Wash. 39.1% 36
Ore. 15.4% 47
Calif. 17.0% 46
Idaho 22.5% 43
Nev. 2.6% 51
Mont. 19.9% 45
Wyo. 22.1% 44
Utah 2.2% 52
Ariz. 26.2% 42
Colo. 73.5% 6
N.M. 62.4% 20
N.D. 65.6% 14
S.D. 67.9% 9
Neb. 48.3% 31
Kan. 50.0% 28
Okla. 53.2% 27
Tex. 56.2% 25
Minn. 73.5% 7
Iowa 63.9% 19
Mo. 54.3% 26
Ark. 39.9% 35
La. 28.7% 41
Wis. 59.8% 22
Ill. 87.8% 2
Mich. 64.9% 17
Ind. 64.3% 18
Ohio 61.5% 21
Ky. 67.2% 10
Tenn. 64.9% 15
Miss. 33.9% 39
Ala. 46.7% 32
Ga. 66.1% 13
Fla. 29.1% 40
S.C. 49.5% 29
N.C. 45.2% 33
Va. 64.9% 16
W.Va. 56.5% 24
Pa. 42.3% 34
N.Y. 66.6% 12
Vt. 37.3% 37
N.H. 13.5% 49
Me. 36.4% 38
Mass. 49.5% 30
R.I. 74.0% 5
Conn.
N.J.
Del.
Md.
D.C.

Alaska	58.4%	23
Conn.	77.9%	3
Del.	66.7%	11
D.C.	100.0%	1
Hawaii	6.3%	50
Md.	76.5%	4
N.J.	13.7%	48
P.R.	72.4%	8

Per cent of state population using fluoridated water and state ranking

Source: Centers for Disease Control

eign phosphate fertilizer industries, spell continued difficulties for U.S. fertilizer production.

Still, the problem is not by-product capacity. Just a few of the phosphoric acid plants could easily supply all the HFSA needed in the U.S. to both municipal water systems and the aluminum industry, the other major consumer. The problem is the periodic gaps in production coupled with a lack of storage capacity. Because the water content of HFSA solution is so high, enormous tank facilities would be required to hold enough acid for more than just a few weeks' supply. But very few municipalities are likely to spend the money on tank farms. As it is, distributors complain that community purchasers will change suppliers on the basis of a marginally lower bid from a competitor. Nor are fertilizer producers interested in building storage capacity for a pesky by-product.

Reeves believes that the installation of storage capacity could be encouraged by state legislatures through either direct funding or tax breaks. The problem with that solution, he concedes, is getting state officials, who are the ones with the authority in the fluoridation effort, interested enough. "I have talked about it with state people," Reeves says, "but nothing has ever been done. The trouble is that nobody's really concerned until there's a shortage, and then it's too late.

"At CDC, we've been urging communities to have more on hand. We get a mixed reaction. Some listen if they're in a state with a good state fluoridation enginee
tend not to listen to u

A shortage of fluor
cals could become seri
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cording to Reeves,
ride in water for
probably would hav
effect on dental health. After a month or so, however, municipal governments would need to consider alerting dentists to the problem. Dentists could then prescribe fluoride tablets or drops to children, something that is now done regularly in many areas in which drinking water is not fluoridated. Fluoridated toothpaste is much less effective than fluoridated drinking water.

Late note →

What worries fluoridation proponents about the pattern of chemical shortages is that shortages sometimes give communities in which opinion is divided a good excuse to drop fluoridation entirely. That holds back the already lagging effort to expand the scope of the water treatment program, which began after World War II. The government's objective has long been to have 95% of the population that is served by public water supplies drinking fluoridated water by 1990. As of last October, the total was 129 million, or about 54%. The chemical shortage does not affect about 10.5 million people in the group; their water systems deliver naturally fluoridated water. The reason for the failure to make fluoridation nearly universal in the U.S. is, as has been the case from the beginning of the effort, opposition by various groups that claim fluoridation is a communist plot and blame it for cancer, AIDS, and other scourges. □

Star Wars Funds Spur University Research

At no time since the height of the Vietnam War have university researchers been as dependent on the Department of Defense for funding as they were in 1985. The Strategic Defense Initiative program, often called Star Wars, is likely to strengthen this dependency in the future, say William Hartung and Rosy Nimroody, researchers affiliated with the New York City-based Council on Economic Priorities.

During the 1980–85 period, DOD has increased its funding for university research 89%, paling the growth in National Science Foundation funding to campuses, which was 51% over that same period. This includes funding for both basic and applied research. If only basic research funding is considered, growth in the funding figures are even more startling: a 118% increase for DOD vs. a 52% increase for NSF.

In 1985, the Pentagon's share of total federal funding for university research was 16%, up from 10% in 1980. That growth rate is nearly twice as fast as any other government source of money. And propelled by funds from the innovative science and technology program within the Pentagon's Strategic Defense Initiative Organization, that rate could reach supersonic speeds in short order. The fiscal 1985 budget for SDIO's innovative program was $28 million. Congress has granted the program a $96 million budget for fiscal 1986. According to John P. McTague, acting director of the Office of Science & Technology Policy, the President is asking that the program's budget be $167 million in fiscal 1987. That rise is occurring as constraints are being placed on other funding sources.

Money from SDIO is not only bountiful but, with less red tape, it is also easier to obtain. With those attributes, SDIO's innovative science and technology program already has received more than 3000 proposals. And Congress willing, SDIO plans to let university contracts within nine months of receiving the "white paper," or proposal. SDIO had planned to let most research contracts for fiscal 1986 by Jan. 1, for instance. But, according to an SDIO spokeswoman, "the continuing budget resolution prevented this."

Nonetheless, SDIO's innovative science and technology program has already committed $62 million for long-term contracts ($15 million in fiscal 1986) to support six research consortia. The money and the challenge to solve technological puzzles have attracted top-notch universities and their associated laboratories. Massachusetts Institute of Technology and its affiliated Lincoln Labs, holders of the most SDI contracts; Johns Hopkins University; Princeton University; the University of California; and the University of Illinois are just a few of the 29 universities in 16 states receiving money to research areas "of critical importance to the success of SDI."

The critical areas being investigated by the consortia are: nonnuclear space power—a $19 million four-year program; composite materials development—a $15 million three-year program; chemical-laser exhaust problems, spacecraft radiation, electromagnetic waves, and particle beams—a $12.5 million three-year program; optical computing—a $9 million three-year project; electronic circuits for computing, sensing, power generation, and directed-energy beams—a $4 million three-year program; and high-speed electronic systems, new dielectric materials for storing power for directed-energy and kinetic-energy systems, and advanced power sources for lasers and particle beams—a $2.5 million three-year project.

Although the head of the innovative science and technology program, James A. Ionson, has said, "Any work for SDI performed on a university campus will not be classified and . . . subject to any control or restrictive clauses or security classifications," qualms remain. The fear is that eventually the secrecy surrounding SDI will constrain academic freedom to publish and disseminate research findings. That fear has compelled more than 2100 faculty members at 43 major research institutions to pledge not to accept research funds.

As Hartung and Nimroody write in their recent report, "Pentagon Invades Academia": "The phenomenal growth of DOD university funding in general, and the SDI innovative science program in particular, threatens the diversity of funding sources and the open research process—essential strengths of scientific research at U.S. universities."

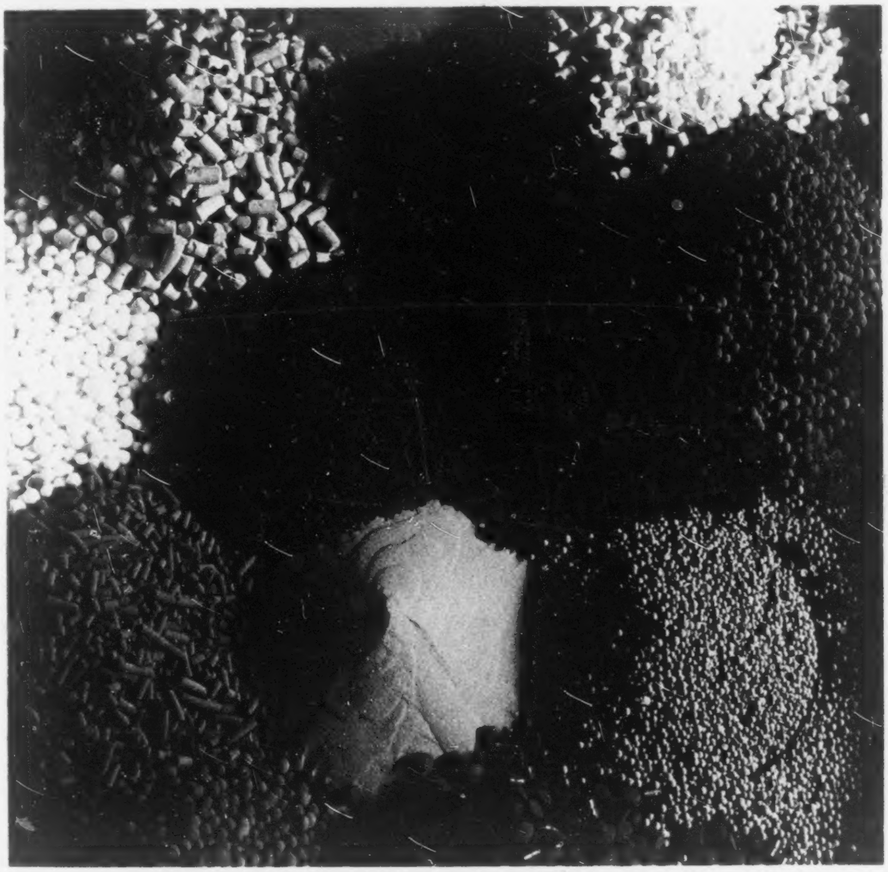
In response to a C&EN query, the SDIO office said: "SDI's innovative science and technology (IST) program spent only $14 million at campuses last year. For fiscal 1986 we anticipate spending about $50 million at campuses, an average of less than $1 million per participating campus. This represents less than 1% of total government funding at universities. All IST research is open on campuses. Also, IST has over 30 research topics, which represents a wide diversity."

Lois Ember, Washington

DOD generously funds university chemistry, chemical engineering

% funding increase, 1980–85	Chemistry	Chemical engineering
BASIC RESEARCH		
Total federal funding	65%	59%
Defense Department funding	127	(−80)
National Science Foundation	79	85
APPLIED RESEARCH		
Total federal funding	13	67
Defense Department funding	50	134
National Science Foundation	200	873

Source: Rosy Nimroody, Council on Economic Priorities, using NSF figures



Hershaw/Filtrol photo

Process Catalysts Continue on Steady Course

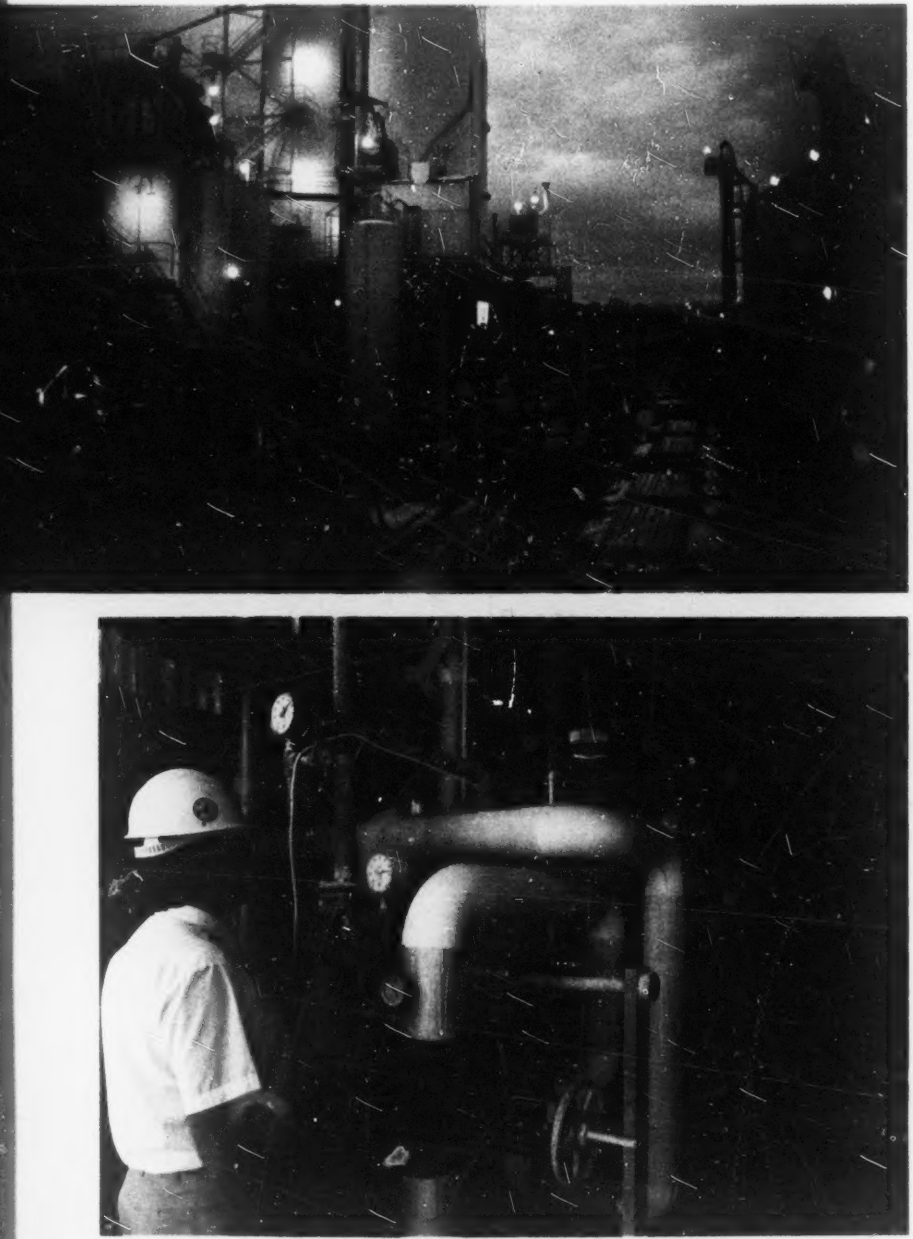
Stephen C. Stinson, C&EN New York

Catalysts have become a large and important business in the U.S.—one marked by slow but steady growth. U.S. sales of process catalysts (those used in refining and chemical processes) reached 4.86 billion lb in 1985, valued at $955 million. Their use is forecast to grow at an annual rate of 2% to 5.4 billion lb in 1990, worth $1.12 billion. Those figures are based on a study of the U.S. catalyst market by the research firm Frost & Sullivan, New York, N.Y.

Process catalysts are used in such petroleum refining processes as alkylation, hydrotreating, hydrocracking, and catalytic cracking and reforming, and in such chemical processes as polymerization, alkylation, oxidation, hydrogenation, and dehydrogenation. Thus process catalysts exclude those that reduce automobile and industrial plant emissions. By custom, the field of process catalysts does include organic peroxides, however, even though they are not true catalysts but initiators of free-radical chain reactions.

As Frost & Sullivan analysts point out, the use of large volumes of commodity chemicals as catalysts distorts any simple picture of this market. These chemicals are aluminum chloride and sulfuric, phosphoric, and hydrofluoric acids for alkylation. For example, of the 4.86 billion lb of process catalysts consumed last year in the U.S., 4.27 billion lb was sulfuric and hydrofluoric acids at refineries, and 90 million lb was phosphoric acid and aluminum chloride in chemical plants. Together, those amounted to 90% of the total volume used. Yet those chemicals were valued at only $210 million, just 22% of the dollar value of total sales.

More than two dozen major firms



W. R. Grace's Davison Chemical division makes several different process catalysts at its Lake Charles, La., manufacturing facility

supply the U.S. market for process catalysts, excluding commodities. Each firm focuses on catalysts that fit its own technologies, which means that there is no universal catalyst company. For example, only eight companies service both the chemical and petroleum industries. Of the eight broad categories of catalytic chemical and refining processes that exclude alkylation, no company supplies catalysts for more than five. Even in the narrow spectrum of the four major catalytic petroleum refining processes besides alkylation, no company makes catalysts for more than three.

Catalyst producers tend to be departments or subsidiaries of larger firms. Though independent catalyst companies have started up from time to time, larger companies soon acquire them. Indeed, the most logical entry into the North American process catalyst market is by acquisition.

Among recent acquisitions, for example, Phillips Petroleum Co. purchased Aztec Chemical Co. (organic peroxides) and PureChem (aluminum alkyl-titanium halide polyolefin catalysts) from Dart & Kraft in 1982. Phillips combined the two companies into one division named Catalyst Resources.

Union Carbide, already in catalysts through its molecular sieves and ethylene oxide process, entered fluid catalytic cracking (FCC) catalysts by buying Katalistiks of Baltimore in 1984. Katalistiks itself had been founded in 1979 by EKA, Göteborg, Sweden, and English China Clays, St. Austell, England, who joined with a group of FCC veterans at Catalyst Recovery International in Baltimore to move into this dynamic field in Europe and the Americas.

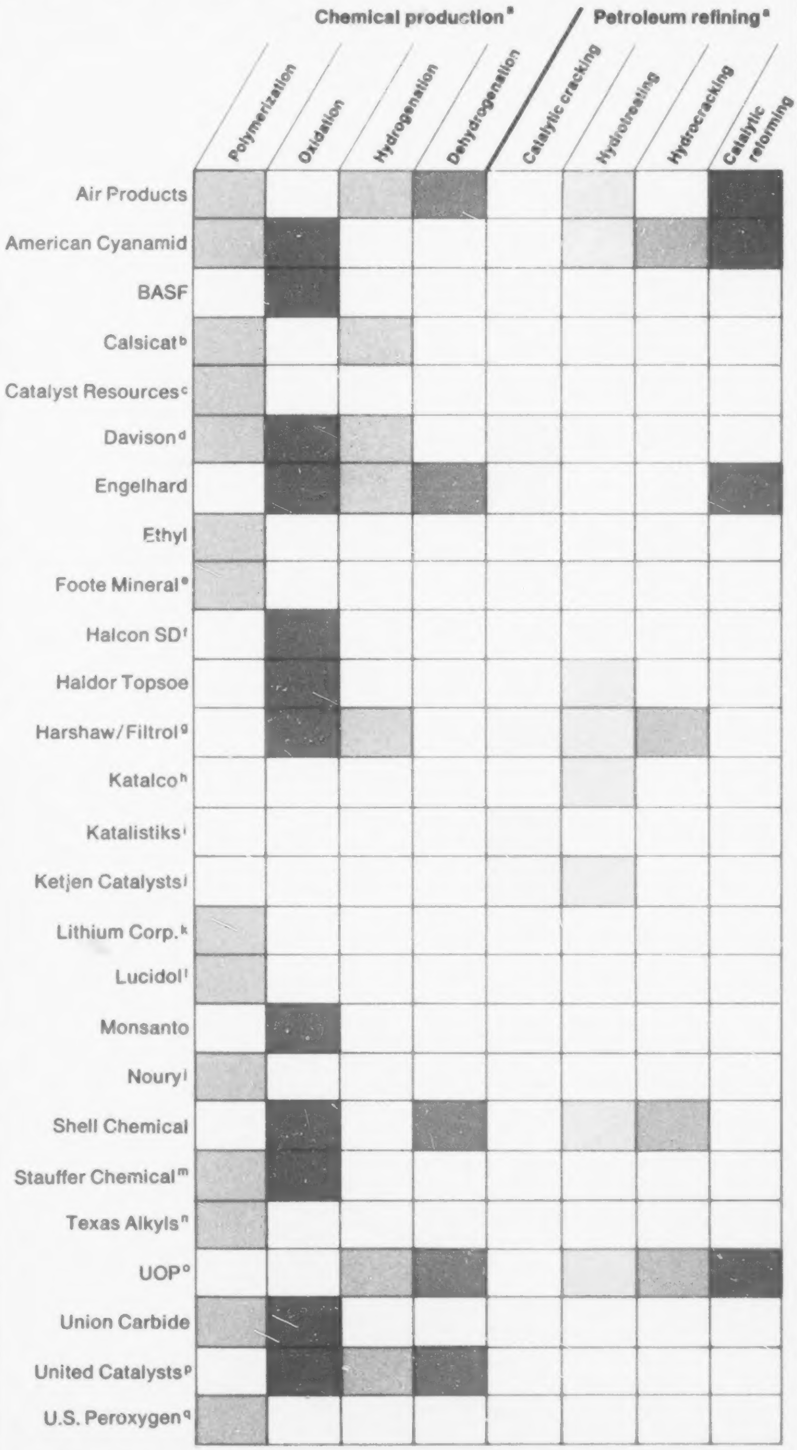
On acquiring Gulf Oil Corp. in 1984, Chevron Corp. found itself in a catalyst-producing joint venture—between Gulf's Harshaw Chemical Corp. and Filtrol Corp. of Kaiser Aluminum & Chemical Co.—called Harshaw/Filtrol Partnership. Harshaw/Filtrol sells catalysts for chemical oxidations and hydrogenations, and for petroleum hydrotreating, hydrocracking, and FCC. Chevron was already a supplier of platinum-rhenium catalytic reforming catalysts.

In recent weeks, Kaiser has reorganized in defense against a hostile takeover. Though such reorganizations are frequently carried out to sell assets, Kaiser probably will keep its share of Harshaw/Filtrol. In fact, Kaiser has until 1989 to decide whether to buy Chevron's share in the joint venture.

And in 1985, Gulf Resources & Chemical Corp. sold its Lithium Corp. of America to FMC Corp. Among Lithco products are lithium and magnesium alkyls for polyolefin catalysts.

Another route into an area of the U.S. catalyst business is expansion from an existing base. For example, Katalistiks started life in the Netherlands with headquarters in Amsterdam and a plant in Delfzijl. After making successful inroads into the European FCC catalyst market, the company opened for business in the U.S. in 1982 and started up a 130

26 firms are major suppliers to U.S. catalyst market



	Chemical production[a]				Petroleum refining[a]			
	Polymerization	Oxidation	Hydrogenation	Dehydrogenation	Catalytic cracking	Hydrotreating	Hydrocracking	Catalytic reforming
Air Products	■		■	■		■		■
American Cyanamid	■	■				■	■	■
BASF		■						
Calsicat[b]	■		■					
Catalyst Resources[c]	■							
Davison[d]	■	■	■					
Engelhard		■	■	■				■
Ethyl	■							
Foote Mineral[e]	■							
Halcon SD[f]		■						
Haldor Topsoe		■				■		
Harshaw/Filtrol[g]		■	■			■	■	
Katalco[h]						■		
Katalistiks[i]								
Ketjen Catalysts[j]						■		
Lithium Corp.[k]	■							
Lucidol[l]	■							
Monsanto		■						
Noury[j]	■							
Shell Chemical		■		■		■	■	
Stauffer Chemical[m]	■	■						
Texas Alkyls[n]	■							
UOP[o]			■	■		■	■	■
Union Carbide	■	■						
United Catalysts[p]		■	■	■				
U.S. Peroxygen[q]	■							

[a] Excludes producers of sulfuric, phosphoric, and hydrofluoric acids, aluminum trichloride, and urethane catalysts. [b] Division of Mallinckrodt. [c] Division of Phillips Chemical. [d] Division of W. R. Grace. [e] Owned 83% by Newmont Mining. [f] Subsidiary of Texas Eastern. [g] Joint venture of Kaiser Aluminum & Chemical and Chevron. [h] Joint venture of Nalco Chemical and Imperial Chemical Industries. [i] Subsidiary of Union Carbide. [j] Division of Akzo Chemie America. [k] Subsidiary of FMC. [l] Division of Pennwalt. [m] Subsidiary of Chesebrough-Pond's. [n] Joint venture of Hercules and Stauffer Chemical. [o] Subsidiary of Allied-Signal. [p] Subsidiary of Sud-Chemie. [q] Division of Witco Chemical. **Source:** Frost & Sullivan

million lb-per-year plant in Augusta, Ga., in 1983.

Akzo Chemie America entered the FCC catalyst business in the U.S. when the Ketjen Catalysts division of the parent company Akzo, long established in Europe, opened a 90 million lb-per-year plant in Pasadena, Tex., in 1985. Among U.S. firms, PQ Corp. has started up a plant in Kansas City, Mo., to make catalyst-type zeolites. The firm had made detergent builder-type zeolites previously. PQ also had made chromium oxide-coated silica catalysts for producing high-density polyethylene by the Phillips process, as well as proprietary, silica-based oxidation catalysts. The Kansas City plant will supply zeolites to catalyst producers as well as make custom catalysts for isomerizations of xylenes and alkylations of benzene in the chemical industry and for hydrocracking, isomerization, and lube oil dewaxing at refineries.

In dollar sales, Davison Chemical division of W. R. Grace & Co., Engelhard, and Harshaw/Filtrol probably are the three largest U.S. suppliers of process catalysts. But because no firm competes exactly head-to-head with any other, estimates of which is "biggest" or which are the "top three" are of doubtful value. In addition, the concentration in precious metal catalysts by companies like Engelhard skews the dollar sales of such companies toward the high side relative to sales of producers whose catalysts use mostly minerals and base metals.

Among catalysts for chemical processes, polymerization catalysts have the greatest dollar sales and seem poised for strongest growth. Figures from Frost & Sullivan indicate that this segment was worth $175 million in 1985, and will grow at almost 5% annually to $220 million by 1990.

One source of change in distribution of polymerization catalyst types will be the continuing growth of linear low-density polyethylene (LLDPE), which will cut into the growth of LDPE. LLDPE uses Ziegler-Natta catalysts, which are combinations of titanium halides with aluminum and magnesium alkyls. Conventional LDPE is made mostly with *tert*-butyl peroctoate, with the

Process catalysts to top $1 billion in 1990

	1985		1990	
	Volume (millions of lb)	Value ($ millions)	Volume (millions of lb)	Value ($ millions)
PETROLEUM REFINING	**4670**	**$545**	**5160**	**$ 620**
Catalytic cracking	370	250	405	275
Reforming	4.5	23	4.7	24
Hydrocracking	1.8	36	2.0	40
Hydrotreating	28	77	38	104
Alkylation	4265	160	4710	177
CHEMICAL PRODUCTION	**190**	**410**	**230**	**500**
Polymerization	50	175	60	220
Alkylation	90	50	110	60
Hydrogenation	9.6	35	11	40
Dehydrogenation	3.7	10	4.6	12
Oxidation, ammoxidation, and oxychlorination	11	85	14	105
Ammonia, hydrogen, and methanol production	26	55	31	60
TOTAL	**4860**	**$955**	**5390**	**$1120**

Note: Figures may not total exactly because of rounding. **Source:** Frost & Sullivan

peracetate, perpivalate, perbenzoate, and perneodecanoate also used.

A second source of change will be the spread of the Montedison process for making polypropylene. Frost & Sullivan analysts speculate that this process uses aluminum alkyls supported on a metal oxide, a catalyst invented by Mitsui Petrochemical Industries. Previously, polypropylene was made by a Ziegler-Natta combination of aluminum alkyls and titanium trichloride.

Montedison and Hercules have formed a joint venture called Himont to commercialize and license the newer technology. Himont and Mitsui have licensed Stauffer Chemical to make and sell the new catalyst in North and South America. Stauffer is a joint-venture partner with Hercules in Texas Alkyls, which makes aluminum alkyls.

A catalytic polymerization still in its infancy is the group-transfer process invented at Du Pont. The technique produces homopolymers and random and block copolymers of such α,β-unsaturated carbonyl monomers as methacrylates. Molecular weight ranges are narrow, and end groups can be chosen to fit the use. The catalyst described by Du Pont chemists is tris(dimethylamino)sulfonium bifluoride, which is available from Carbolabs, New Haven, Conn. It is uncertain what catalysts will be used in commercial resin production or what their economic value may be.

Group-transfer polymerization is initiated by a trimethylsilyl ketal such as dimethylketene methyl trimethylsilyl ketal. Polymerization occurs at room temperature. With addition of each α,β-unsaturated monomer molecule to the chain, the trimethylsilyl group transfers to the new carbonyl oxygen. That transfer creates a new trimethylsilyl ketal group on the growing end of the chain. Chain sequence is controlled by the composition of the monomer mixture or the order of monomer addition. The nature of the end groups depends on the compounds used as initiators and chain-terminators.

After polymerization, oxidation is the second largest market segment for chemical process catalysts, according to Frost & Sullivan researchers. This segment includes ammoxidation catalysts for production of acrylonitrile from propylene, ammonia, and oxygen, and oxychlorination catalysts for conversion of ethylene to ethylene dichloride. Chemical plants used 11 million lb of oxidation catalysts in 1985, worth $85 million. That amount will increase at more than 4% annually to 14 million lb in 1990, valued at $105 million.

Favorable economics may shift production of methacrylonitrile in coming years to ammoxidation of a mixed butene stream, say analysts at Catalytica Associates, Mountain View, Calif., a catalyst development research firm. So concludes the company in a study of the impact of future catalyst developments on the chemical industry. The current process is reaction of acetone and hydrogen cyanide to the cyanohydrin, followed by dehydration. Such a shift would increase consumption of ammoxidation catalysts.

But a shift away from acetone and hydrogen cyanide may be averted by the pricing of those compounds, which are both by-products. Acetone is a by-product of phenol production, and hydrogen cyanide is a by-product of the acrylonitrile process.

Other major catalytic chemical processes are hydrogenation and dehydrogenation. Hydrogenation catalysts can be platinum or palladium on supports or a finely divided nickel called Raney nickel. Industrial hydrogenations include conversion of benzene to cyclohexane, phenol to cyclohexanone for caprolactam production, edible oils to shortenings, inedible oils to saturated fatty acids as rubber additives, and a mixture of 20% 2,6- and 80% 2,4-dinitrotoluene to toluenediamines as an intermediate in toluene diisocyanate production.

Dehydrogenation catalysts are generally aluminum, chromium, and/or ferric oxides. Commercial dehydrogenations include conversion of butane to butenes, butenes to butadiene, and ethylbenzene to styrene.

Frost & Sullivan analysts predict almost 7%-per-year increases in use of hydrogenation catalysts to 11 million lb worth $40 million in 1990 from 9.6 million lb valued at $35 million in 1985. The firm forecasts nearly 4% growth yearly for dehydrogenation catalysts to 1.2 million lb in 1990, worth $4.6 million, from 1 million lb in 1985, valued at $3.7 million.

Among refinery catalysts, fluid catalytic cracking (FCC) catalysts have the greatest volume and show the fastest growth, according to Frost & Sullivan. Consumption of FCC catalysts will increase at almost 5% per year to 405 million lb in 1990, valued at $275 million, from 370 million lb in 1985, worth $250 million.

One reason for such high volumes and growth is the crucial role of FCC in increasing the yield of gasoline. From 35 to 60% of crude oil may pass through the "cat cracker" during refining. FCC converts gas oils at process temperatures from 400 to 700 °F to lighter hydrocarbons. Atmospheric gas oil (AGO) is a distillate boiling from 530 to 650 °F. Vacuum gas oil, taken off at 0.15 atm after AGO passes over, has a theoretical atmospheric boiling range of 650 to 1050 °F. FCC also increases the content of branched-chain and aromatic hydrocarbons, which raise gasoline octane levels.

A second reason for high volumes and growth of FCC catalysts is that they must be replaced more often than those for other refining processes.

Such a large market segment has attracted recent competition. Until 1982, Davison sold about 50% of FCC catalysts used in the U.S., Engelhard 30%, and Filtrol 20%, say Frost & Sullivan researchers. In 1982, Katalistiks opened a U.S. sales office, and in 1985, Akzo Chemie America's Ketjen Catalysts division started its 90 million lb-per-year plant in Pasadena, Tex. At present, Katalistiks sells an estimated 10% of U.S. FCC catalysts and Ketjen 5%, with Davison, Engelhard, and Harshaw/Filtrol having lost slightly in proportion. The result has been lower prices as catalyst producers have fought to win or keep market share.

Davison, for example, has restructured its business to reduce costs and has kept up its research and technical service programs, says James J. Blazek, technical vice president. One technical service effort is analysis of equilibrium catalysts for refiners, regardless of whether those refiners are Davison customers. The company's technicians now analyze 7000 samples of equilibrium catalyst daily for about two dozen such characteristics as activity, surface area, and metals content with a turnaround time of five days. Samples come from 97% of all refineries in the U.S. and Canada.

Equilibrium catalyst is the total catalyst that is actually in the fluid catalytic cracker at any one time. Refiners periodically add a portion of fresh catalyst to the cracker. Changes in feedstock or operating conditions also affect the total state of the catalyst, and analyses of equilibrium catalysts reflect trends or problems. For example, hydrothermal deactivation from the leakage of water or steam into the catalyst regenerator produces different changes in pore volume, average pore diameter, and apparent bulk density from purely thermal deactivation.

FCC catalysts are zeolites supported on aluminum silicates. The dozen or so types differ as to particle size and zeolite composition, which may range from all-natural to all-synthetic. In addition to marketing a broad line of these types, Davison also supplies catalysts

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treated with additives to tailor them to particular refinery needs. Product manager John Juracek Jr. calls additives the company's handle on supplying custom catalysts.

One such additive, a noble metal supported on alumina, promotes the combustion of carbon monoxide to carbon dioxide in the regenerator. Another, a metal salt, promotes oxidation of sulfur dioxide to the metal sulfate, which is reduced to hydrogen sulfide for removal on return of the catalyst to the cracker.

Although all such additives are vital to their functions, perhaps the most important just now are proprietary zeolites for octane enhancement. That's because the Environmental Protection Agency is following a schedule for gradually eliminating lead additives in gasoline. Refiners find that using so-called octane catalysts on the huge volumes of hydrocarbons that flow through their FCC units is more economical than adding catalytic reforming capacity or blending oxygenated additives into the gasoline. Octane catalysts contribute two to three more octane numbers to gasoline in comparison with conventional FCC catalysts.

About two more octane numbers result from increasing the olefin content and one number from raised aromatics levels. The Davison octane additive lowers the yield of gasoline and produces more C_3 and C_4 hydrocarbons. Refiners can subject the C_3-C_4 stream to alkylation, however, to restore some gasoline yield.

Indeed, alkylation catalysts are the most valuable class of refinery catalysts after those for FCC. One example of alkylation is reaction of isobutane with propylene. Although hydrofluoric acid is more costly than sulfuric, it is coming into wider use to catalyze alkylations owing to the fewer environmental problems with its use.

Frost & Sullivan analysts note that hydrofluoric acid was used in 40% of alkylation capacity in 1978 and in 46% by 1983. Slow, steady growth at 2% per year is forecast for those commodity acids to 4.71 billion lb worth $177 million in 1990 from 4.27 billion lb valued at $160 million in 1985. Many chemical companies supply sulfuric acid and hydrofluoric acid to refineries, and many refineries have their own sulfuric acid plants.

After FCC and alkylation, two other important refining processes are hydrotreating and hydrocracking. Hydrotreating is a mild hydrogenolysis of nitrogen, oxygen, and sulfur compounds and olefins to ammonia, water, hydrogen sulfide, and paraffins. The output stream from the hydrotreater goes to the cat cracker. Hydrocracking is catalytic cracking of refining residues to lighter, more highly branched hydrocarbons in the gasoline range in a hydrogen atmosphere. The output stream from hydrocracking is defi-

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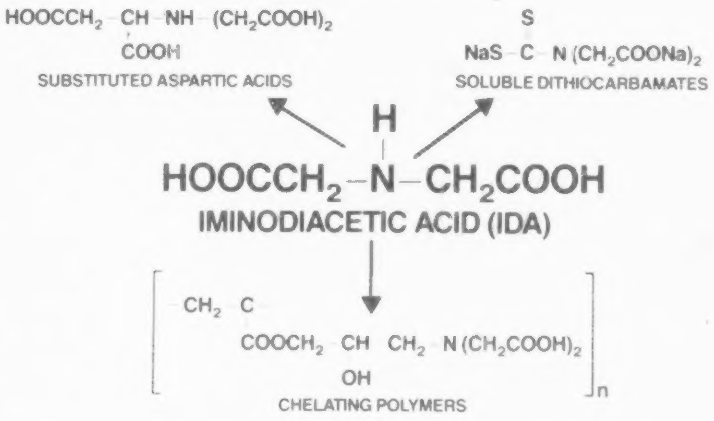

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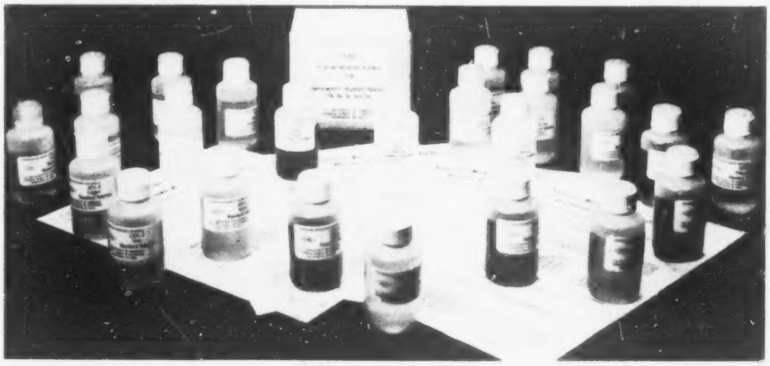

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cient in octane-building olefins and aromatics and must usually be upgraded in octane by catalytic reforming. Hydrocracking of naphtha is also a source of petroleum gases.

Hydrotreating catalysts are cobalt or nickel molybdate or nickel tungstate on an alumina or zeolite support. The composition of metal salts varies according to whether the emphasis is on desulfurization or denitrification. Akzo Chemie America, American Cyanamid, Katalco, and Shell Chemical supply 90% of the U.S. market.

Hydrocracking catalysts include nickel, cobalt, molybdenum, tungsten, platinum, or palladium on aluminum silicate or zeolite supports. The leading suppliers to U.S. refineries are American Cyanamid, Shell Chemical, and UOP, a subsidiary of Allied-Signal, with some participation by Harshaw/Filtrol.

The level of activity of both hydrotreating and hydrocracking increases with refining of heavier, dirtier, more sour crudes. Though industry observers predict a bright long-term future for catalysts of these processes, the current ample supply of light, sweet crudes will restrict their growth for an indefinite time to come. Thus the FCC unit will keep its title as gasoline machine at U.S. refineries for now. Growth of hydrotreating catalysts also is restricted by activity to regenerate them in forms as active as fresh catalyst.

Frost & Sullivan studies indicate that hydrotreating catalyst use will rise at 6% yearly to 104 million lb worth $38 million in 1990 from 77 million lb valued at $28 million in 1985. Hydrocracking catalysts will grow at an average annual rate of about 2% to 40 million lb worth $2 million in 1990 from 36 million lb valued at $1.8 million in 1985.

A fifth major catalytic refinery process is catalytic reforming. That process dehydrogenates and isomerizes naphtha at 850 to 1000 °F to increase its content of branched-chain hydrocarbons and aromatics. Hydrogen from reforming goes to hydrotreating and hydrocracking. Reforming catalysts are platinum or platinum plus rhenium supported on alumina. American Cyanamid,

Continued on page 46

Harshaw/Filtrol researcher prepares to calcine catalyst in oven

Engelhard, and UOP have about 75% of the U.S. reforming catalyst market.

Levels of reforming activity at refineries vary directly with gasoline demand and inversely with the amounts of lead additives allowed in gasoline. Because they expect gasoline demand to decline over the next five years, Frost & Sullivan analysts predict only 0.5% annual growth in reforming catalyst consumption during the period. U.S. refineries used 4.5 million lb of such catalysts, worth $23 million, in 1985. In 1990, they will use 4.7 million lb, valued at $24 million.

Although not strictly a refining step, the Claus process to recover sulfur from hydrogen sulfide in refinery gases is an important one. This process oxidizes part of the hydrogen sulfide to sulfur dioxide, which is then combined with more hydrogen sulfide to produce sulfur. Alumina is the catalyst. Such firms as Harshaw/Filtrol supply the catalysts, and this company recently has developed a proprietary nonalumina catalyst that is said to function exceptionally well when carbon disulfide and carbonyl sulfide are present in the gases. Those compounds could be produced if hydrocarbons get into the reactor.

Although catalysts are already important in chemical and oil-refining processes, their roles are expected to expand vastly in coming years as research uncovers new catalyst substances and catalytic processes. Harold Witcoff of Chem Systems, London, says the catalyst-producing industry has several objectives for the future, including the advance of catalysis theory to a priori catalyst design, improving selectivities in processes currently carried out, improving catalyst activity, deriving catalysts for new reactions, and devising stereoselective catalysts.

Witcoff has identified many promising areas of future research in a study on selected catalyst developments he did for Chem Systems, which is headquartered in Tarrytown, N.Y. These areas include phase-transfer catalysts, catalysts for asymmetric synthesis, multifunctional catalysts, intercalated catalysts, and zeolites.

Phase-transfer catalysts are usually quaternary ammonium salts, which are compatible with both water and organic solvents. The quaternary cations usher reactants and products back and forth between immiscible liquids. Phase-transfer catalysts mediate reactions of nonpolar with polar or ionic reactants. Without them, industrial chemists might have to use costly solvents, such as dimethylformamide, that are difficult to recover, or multiply the number of steps needed to make a product.

Witcoff points out that the most important current phase-transfer catalytic process is production of polycarbonate resins from bisphenol A and phosgene. A quaternary ammonium salt brings phosgene out of methylene chloride into a sodium hydroxide solution of bisphenol A for reaction. The resin is extracted back into the methylene chloride. Thus phase-transfer catalysis mediates a reaction between a water-sensitive, nonpolar gas and an ionic salt. Before the invention of this process, resin makers converted phosgene to diphenyl carbonate, transesterified this with bisphenol A, and distilled the phenol for reuse.

A second current use is esterification of ampicillin into a prodrug. A prodrug is a compound that lasts longer in the body, because the prodrug must be converted to active compound to exert its effect. In addition, some prodrugs are better able to reach some sites of the body than the active drugs. In phase-transfer catalytic esterification of ampicillin, a quaternary ammonium salt brings an alkyl bromide out of chloroform into an aqueous solution of the potassium salt of ampicillin. The ester is extracted into the chloroform after reaction at room temperature. Alternative esterification reactions run the risk of hydrolyzing the β-lactam ring.

The most important catalytic process for asymmetric synthesis is that developed by Monsanto to hydrogenate an α-acetaminocinnamic acid to an L-hydrocinnamic acid, which is an intermediate for production of L-dihydroxyphenylalanine (L-dopa), a drug used to treat Parkinson's disease. The catalyst is a chelate of rhodium(I) with optically active bis(phenyl-2-methoxyphenylphosphino)ethane. Witcoff suggests that the process might be adapted to making L-phenylalanine, an intermediate in production of the sweetener aspartame.

Another catalytic asymmetric synthetic technique that might find wide commercial use is the asymmetric epoxidation of allylic alcohols. The method was invented by organic chemistry professor K. Barry Sharpless of Massachusetts Institute of Technology. In such reactions, titanium tetraisopropoxide and diethyl D- or L-tartrate mediate epoxidation by *tert*-butyl hydroperoxide. Chemists can select the epoxide enantiomorph to be produced by choosing the appropriate tartrate isomer. Simply sketching out the structure of the allylic alcohol lets chemists predict which enantiomorph will result.

Candidates for catalytic asymmetric syntheses include drugs and insect pheromones. Often only one optical isomer of a drug is active and the other either inactive or harmful. For pheromones, making only the active enantiomorph produces a more potent compound for pest control.

A technique that achieves asymmetric synthesis by phase-transfer catalysis has been invented by process engineering chemists at Merck Sharp & Dohme. Their process alkylates 6,7-dichloro-5-methoxy-2-phenyl-1-indanone to the *S*-(+)-2-methyl compound with methyl chloride in 92% enantiomeric excesses and 95% yields. The optically active phase-transfer catalyst is *N*-*p*-trifluoromethylbenzylcinchoninium bromide, and the solvents are aqueous sodium hydroxide and chloroform-toluene. The product is an intermediate in production of *S*-(+)-indacrinone.

Worker tests catalyst at Engelhard's Menlo Park, N.J., research facility

S-(+)-Indacrinone is a drug that eliminates uric acid through the urine to keep a proper balance of that compound in the body. The *R*-(-)-isomer increases urine production and sodium excretion. Disorders of uric acid metabolism include gallstones and gout. Increased urine production and sodium excretion aid in treating hypertension. Controlling the ratios of both enantiomorphs may produce the optimum level of each type of drug activity.

Among the multifunctional catalysts for which Witcoff sees much future promise, the most important in current use is one for catalytic reforming. A multifunctional catalyst has two different kinds of active sites that are close to one another. One kind of active site catalyzes a reaction of the product formed at the other. Continuous conversion of the intermediate product shifts the equilibrium to keep the overall reaction going.

The reforming catalyst has a noble metal supported on silica. Acidic sites on silica mediate such conversions as methylpentanes to cyclohexane. The noble metal dehydrogenates cyclohexane to benzene. The overall effect is to increase the amounts of aromatics formed.

Both the intercalated catalysts and zeolites whose potential Witcoff has studied are examples of shape-selective catalysts. The interstices of these minerals are of sizes and shapes that allow entry or exit of some molecules but not others. Intercalated catalysts, also called pillared clays, have large spaces between layers.

One such clay, smectite, was the original cracking catalyst at oil refineries in the 1930s. When zeolites with their smaller cavities were found superior, refiners abandoned smectite. The only commercial use of pillared clays today is conversion of oleic acid to dimer acid.

Nevertheless, Witcoff says that catalyst researchers are reinvestigating pillared clays, because the many useful processes that have been developed around zeolites suggest a bright future for shape-selective catalysts generally. One possibility he cites is polymerization. The cavities between layers may produce uniform molecular weight distributions, and the cavities may be large enough to allow polymer molecules to exit after formation.

But pillared clays may be useful to catalyze reactions of any large molecules. Steroids and antibiotics are of such a molecular size that may fit into the interstices of pillared clays but not those of zeolites.

The biggest use for zeolites is in fluid cracking catalysts. Witcoff says that much work is under way to develop hydrocracking catalysts based on them also. Zeolites doped with metals might yield catalysts that are more active and less susceptible to poisoning, and that produce more-uniform products.

Another important use is production of ethylbenzene, where zeolites are replacing aluminum chloride. Zeolite catalysts are also used in the Mobil-Hoechst process to make *p*-methylstyrene. Those catalysts produce preferentially the *p*-ethyltoluene precursor from toluene and ethylene. Other alkylation processes for toluene give a mixture of ortho, meta, and para isomers. The end-product mixture, called vinyltoluene, is used as a crosslinking agent in unsaturated polyesters.

Plastics producers were interested in *p*-methylstyrene to replace styrene because of the high cost of benzene relative to toluene during the oil shortages of the past decade. The current plentiful supply of oil and low price of benzene have forced abandonment of *p*-methylstyrene. But a return of oil shortages could encourage producers to take up the process again.

Mobil Chemical has developed a zeolite-catalyzed process to convert methanol made from synthesis gas to gasoline. Another Mobil process not used now converts methanol to olefins, mostly propylene and butylenes, which can be polymerized to gasoline and middle distillates. UOP has developed a zeolite-catalyzed process to make methylated benzenes from ethane and propane. All of these technologies make gasoline and octane-raising components, and they could become useful with the recurrence of oil shortages. □

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CHEMICAL & ENGINEERING NEWS

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ACS meeting in New York City
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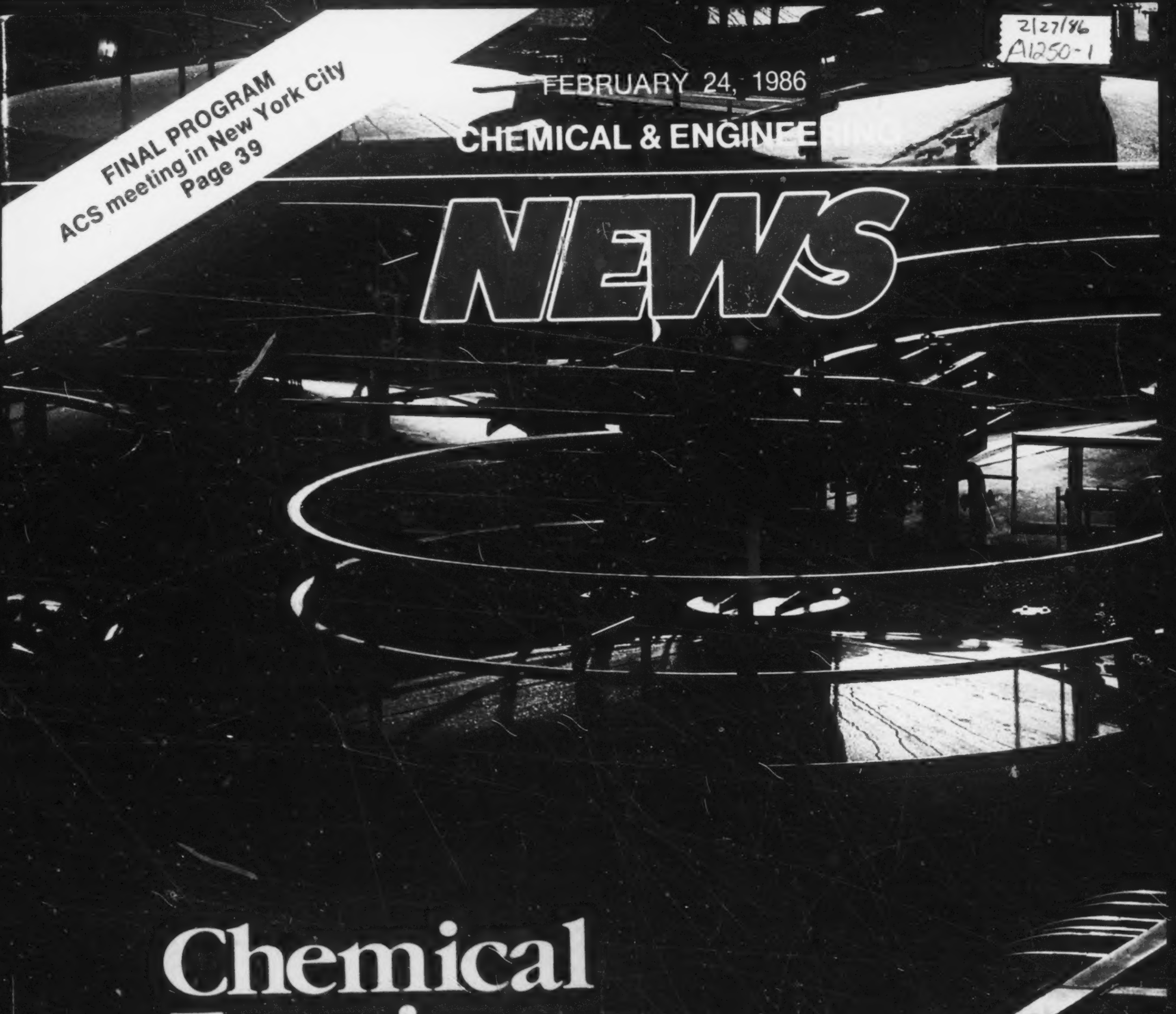

Chemical Earnings

Fifth straight quarterly decline
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CHEMICAL & ENGINEERING NEWS

FEBRUARY 24, 1986

News of the Week

- **NSF grant holders face cuts of up to 10% in fiscal 1986 under Gramm-Rudman-Hollings Act.** Page 4
- **So-called "spy dust" found in U.S. embassies in the U.S.S.R. is not a health hazard, tests show.** Page 5
- **Oberlin College marks centennial of discovery of electrolytic process for producing aluminum.** Page 5
- **Du Pont to require job applicants, some employees to undergo testing for illegal drug use.** Page 5
- **Iraq apparently is using chemical weapons in Iranian war.** Page 6
- **Fertilizer demand in North America in 1986 will be flat or down slightly from 1985 levels, marketers forecast.** Page 6

Cover: Photo courtesy of Interox America

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Large drug firms still dominate biotechnology-related patent activity in the U.S. **Page 17**

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Funding for federal regulatory agencies increases only slightly in the Administration's proposed budget. **Page 27**

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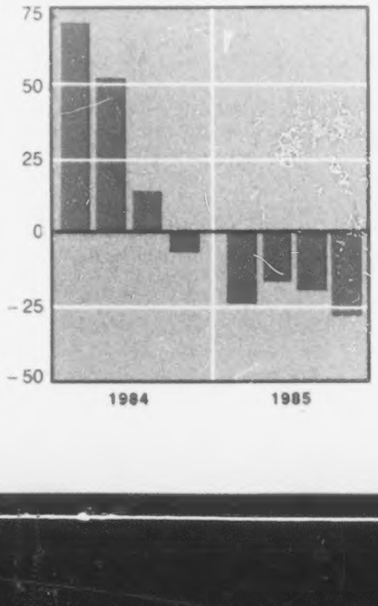
Technique that improves deposition of gallium arsenide onto silicon wafers is developed at University of Illinois. **Page 33**

Glass-cracking study at Sandia National Laboratories may lead to more-reliable glass/ceramic products. **Page 34**

Earnings

% change from year-earlier quarter



Cover Story

Fourth-quarter earnings continue downward trend for the U.S. chemical industry, sending full-year profits down from 1984 levels. **Page 10**

Chemical Earnings Continued Downward Trend in Fourth Quarter

William J. Storck, C&EN New York

Earnings for the U.S. chemical industry fell once again in the fourth quarter, sending full-year profits down from 1984 levels. The weakness in earnings also affected the oil and gas producers with chemical operations and diversified companies that include chemicals in their portfolios.

However, the fourth quarter was a period of transition and positioning for the U.S. chemical industry. Many companies, as is customary, used the fourth quarter to write down marginal operations, to dispose of businesses, and to cut employment in an effort to increase productivity.

It also may prove to have been a period of transition in another way. Although earnings for some companies were down from the same period the year before, and in some cases showed losses, many other companies had large increases in earnings. Some industry observers say that this is the pattern before a turnaround in chemicals—that there will be wide diversity of results among producers. If this proves to be true, it certainly bodes well for the first part of this year.

Companies themselves were preparing for 1986. Firms such as Monsanto, Reichhold Chemicals, American Cyanamid, Union Carbide, and others took large nonrecurring charges from the sale of operations, early retirement incentive and layoff programs, and shuttering of operations. That trend was so pervasive and the result was so large that if the nonrecurring items were not ex-

Chemical industry leaders for the fourth quarter. . .

Sales Rank 1985		$ Millions	Rank 1984
1	Dow Chemical	$2909.0	1
2	Union Carbide	2320.0	2
3	W. R. Grace	2013.2	3
4	Monsanto	1760.0	4
5	PPG Industries	1100.0	5
6	American Cyanamid	890.0	6
7	Celanese	760.0	7
8	National Distillers	649.1	9
9	Hercules	636.2	8
10	Morton Thiokol	480.4	11

Earnings[a]	$ Millions	Rank 1984
PPG Industries	$59.0	1
Celanese	50.0	8
W. R. Grace	44.7	2
American Cyanamid	38.7	3
Ethyl	37.9	6
Union Carbide	37.5	16
Air Products	34.4	9
Morton Thiokol	32.0	10
Hercules	31.0	4
Rohm & Haas	24.7	11

Profitability	Earnings as % of sales	Rank 1984
International Flavors	12.0%	1
Freeport-McMoRan	10.5	2
Nalco Chemical	10.0	3
Ethyl	10.0	4
Loctite	8.5	5
Air Products	7.2	8
Morton Thiokol	6.7	11
Celanese	6.6	17
PPG Industries	5.4	12
Rohm & Haas	5.2	13

. . . and for full-year 1985

Sales Rank 1985		$ Millions	Rank 1984
1	Dow Chemical	$11,537.0	1
2	Union Carbide	9,000.0	2
3	W. R. Grace	7,260.1	3
4	Monsanto	6,750.0	4
5	PPG Industries	4,300.0	5
6	American Cyanamid	3,536.1	6
7	Celanese	3,046.0	7
8	Hercules	2,587.0	8
9	National Distillers	2,289.0	9
10	Rohm & Haas	2,051.2	10

Earnings[a]	$ Millions	Rank 1984
PPG Industries	$303.0	3
Union Carbide	251.3	2
Monsanto	213.0	1
Celanese	182.0	8
Air Products	145.8	9
American Cyanamid	142.9	4
Hercules	142.1	6
Rohm & Haas	141.2	7
Ethyl	137.1	10
Morton Thiokol	126.5	11

Profitability	Earnings as % of sales	Rank 1984
International Flavors	13.9%	1
Freeport-McMoRan	11.1	3
Nalco Chemical	10.7	2
Loctite	9.3	4
Ethyl	8.9	9
Air Products	7.8	7
Petrolite	7.2	5
PPG Industries	7.0	11
Rohm & Haas	6.9	6
Morton Thiokol	6.7	14

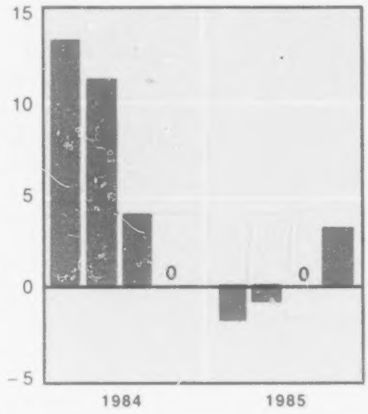
[a] After taxes. **Note:** Based on 30 companies listed on page 12.

Chemical industry 1985 fourth-quarter results

- Sales were up slightly
- Earnings faltered
- Profit margins fell to 3.1%
- Production rose 2.6%
- Prices were level

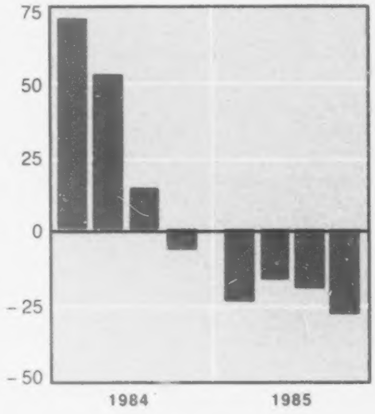
Sales

% change from year-earlier quarter



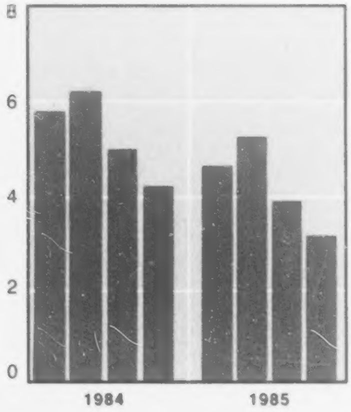
Earnings

% change from year-earlier quarter



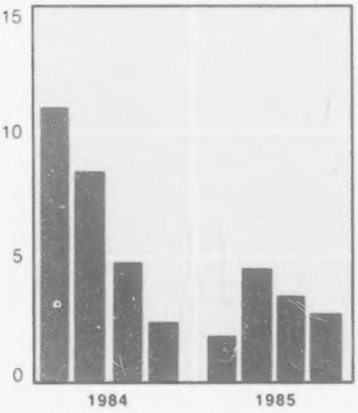
Profit margins

After-tax earnings as % of sales



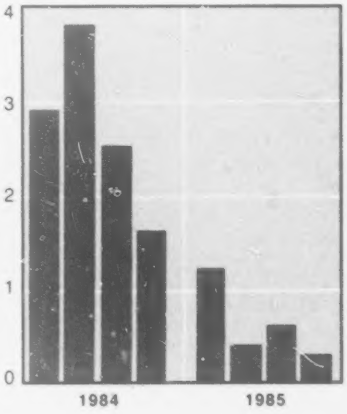
Production

% change from year-earlier quarter



Prices

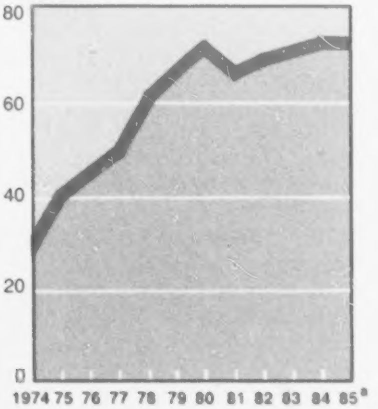
% change from year-earlier quarter



Sales for 1985 were flat, but profits fell 16%, dropping profit margins to lowest level since 1981

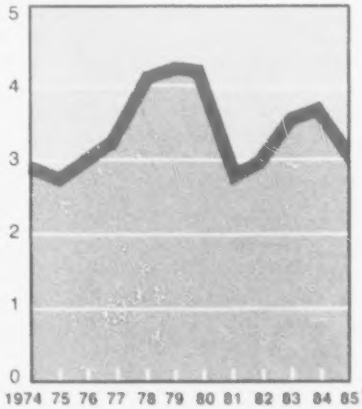
Annual sales

$ Billions



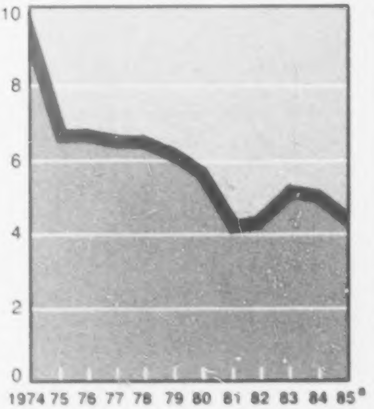
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



a C&EN estimates. **Note:** All sales, earnings, and profit-margin data are based on combined results of the 30 companies listed on page 12.

Earnings, profit margins continued to fall in fourth quarter

	FOURTH-QUARTER 1985						FULL-YEAR 1985					
	Sales	Earnings[a]	Change from 1984		Profit margin[b]		Sales	Earnings[a]	Change from 1984		Profit margin[b]	
	($ millions)		Sales	Earnings	1985	1984	($ millions)		Sales	Earnings[a]	1985	1984
Air Products[c]	$ 475.9	$ 34.4	9%	7%	7.2%	7.4%	$ 1,869.9	$ 145.8	7%	5%	7.8%	7.9%
American Cyanamid[c]	890.0	38.7	0	−17	4.3	5.2	3,536.1	142.9	0	−28	4.0	5.6
Celanese[c]	760.0	50.0	−8	52	6.6	4.0	3,046.0	182.0	−8	12	6.0	4.9
Chemed	94.2	4.4	5	26	4.6	3.8	372.7	17.9	8	−2	4.8	5.3
Chesebrough-Pond's	na	na	na	na	na	7.5	na	na	na	na	na	6.4
Crompton & Knowles	57.2	2.3	8	17	4.1	3.8	231.2	7.6	0	−4	3.3	3.4
Dow Chemical[c,d]	2,909.0	−314.0	8	def	def	2.6	11,537.0	58.0	1	−86	0.5	3.6
Essex Chemical	na	na	na	na	na	7.4	na	na	na	na	na	4.0
Ethyl	379.4	37.9	−2	−1	10.0	9.9	1,547.0	137.1	−8	8	8.9	7.6
First Mississippi	73.8	3.1	15	−35	4.2	7.3	282.2	12.6	−2	−42	4.4	7.5
Freeport-McMoRan	155.1	16.3	−28	−35	10.5	11.5	722.2	80.4	−14	−12	11.1	10.9
H. B. Fuller	116.7	4.2	5	26	3.6	3.0	457.9	13.3	2	2	2.9	2.9
W. R. Grace[c]	2,013.2	44.7	8	−21	2.2	3.0	7,260.1	106.0	6	−46	1.5	2.9
Hercules[c]	636.2	31.0	3	−30	4.9	7.1	2,587.0	142.1	1	−28	5.5	7.7
International Flavors	122.3	14.6	18	18	12.0	12.0	501.0	69.7	5	1	13.9	14.5
International Minerals	341.2	3.3	−10	−90	1.0	9.1	1,535.2	55.2	−4	−47	3.6	6.4
Loctite	65.2	5.6	12	1	8.5	9.4	239.9	22.4	−2	−13	9.3	10.6
Lubrizol	na	na	na	na	na	6.8	na	na	na	na	na	8.1
Monsanto[c]	1,760.0	−59.0	13	def	def	2.6	6,750.0	213.0	1	−51	3.2	6.6
Morton Thiokol[c]	480.4	32.0	8	10	6.7	6.5	1,888.5	126.5	2	11	6.7	6.2
Nalco Chemical	184.8	18.5	11	8	10.0	10.3	682.3	73.3	3	0	10.7	11.0
National Distillers[c]	649.1	17.9	11	16	2.8	2.6	2,289.0	60.3	2	−21	2.6	3.4
Olin[c]	390.6	8.4	−10	6	2.1	1.8	1,751.1	39.7	−3	−46	2.3	4.1
Pennwalt	258.4	6.2	6	−46	2.4	4.7	1,013.3	11.2	3	−75	1.1	4.6
Petrolite	80.2	3.6	7	−49	4.5	9.4	309.0	22.4	5	−13	7.2	8.8
PPG Industries[c]	1,100.0	59.0	0	−11	5.4	6.0	4,300.0	303.0	2	0	7.0	7.2
Reichhold Chemicals	193.6	−10.9	9	def	def	3.3	822.5	0.4	3	−98	0.1	3.2
Rohm & Haas[c]	470.7	24.7	4	−2	5.2	5.5	2,051.2	141.2	0	−18	6.9	8.4
Union Carbide[c]	2,320.0	37.5	−3	188	1.6	0.5	9,000.0	251.3	−5	−26	2.8	3.6
Witco Chemical	347.8	15.1	−6	−23	4.3	5.3	1,448.8	56.8	−3	−16	3.9	4.5
Total 13 largest firms[e,f]	**$12,287.2**	**$322.6**	**3%**	**−27%**	**2.6%**	**3.7%**	**$47,864.1**	**$1909.0**	**0%**	**−24%**	**4.0%**	**5.2%**
Smaller 13 firms[e]	**$ 2,128.7**	**$120.9**	**0%**	**−23%**	**5.7%**	**7.4%**	**$ 8,630.3**	**$ 525.1**	**−2%**	**−14%**	**6.1%**	**7.0%**
GRAND TOTAL[f]	**$14,415.9**	**$443.6**	**2%**	**−26%**	**3.1%**	**4.3%**	**$56,494.5**	**$2434.1**	**0%**	**−22%**	**4.3%**	**5.5%**

a Excludes significant extraordinary and nonrecurring items. **b** After-tax incomes as a percentage of sales. **c** One of 15 largest firms. **d** Includes substantial nonrecurring charge. **e** For those firms reporting. **f** Excludes Dow Chemical results because of large nonrecurring item. **na** = not available at press time. **def** = deficit.

cluded, earnings for 30 of the largest chemical companies surveyed by C&EN would have been almost wiped out. And this does not include a huge pretax charge of $592 million at Dow Chemical. Dow would not break out an after-tax figure for its charge, thus cannot be included.

Other problems, however, remained the same in the fourth quarter as they had been in the previous four quarters or longer. The agricultural economy continued to lag and many purchases of agricultural chemicals, especially fertilizers, were delayed into the first quarter of this year as farm suppliers expected lower prices with the fall in natural gas

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 36 oil and diversified companies, each with more than $200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 40% of its sales in chemicals, and its chemical operations must be the largest single portion of the company operations. That is why Du Pont, for example, is not included as a basic chemical producer but rather as a diversified manufacturer.

In referring to chemical sales, C&EN means sales of those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

prices. In addition, with the ailing farm economy and some crop setaside programs, suppliers have been reluctant to build up inventories in anticipation of somewhat shaky demand forecasts.

Other problems also continue for chemical producers. These include foreign trade competition brought on in part by the strong dollar against foreign currencies and a weak chemical pricing structure, especially for petrochemicals. Expectations are for the foreign trade picture to brighten as the dollar's value falls against other currencies. However, with oil prices falling and putting pressure on petrochemicals, it is still anybody's guess how likely any firming might be. Sources say the most that can be hoped for is lower feedstock costs for chemical producers. Thus, if margins are to increase, it probably will be from the supply rather than from the demand side.

As a result, combined earnings for the fourth quarter for 26 of the 30 companies normally surveyed by C&EN fell 26% from fourth-quarter 1984 to a total of nearly $444 million. Chesebrough-Pond's, Essex Chemical, and Lubrizol had not reported fourth-quarter results by press time. And Dow has been left out of the averages because, with the inability to eliminate its huge nonrecurring charge, it would skew the averages far too much. Combined sales for the group were up 2% to a total of $14.4 billion. As a result, profit margins (after-tax earnings as a percentage of sales) fell to an average of 3.1% from 4.3% in the fourth quarter of 1984.

The smaller companies did not fare quite so poorly as the larger ones. For the 13 smaller firms reporting, cumulative earnings in the fourth quarter decreased 23% from a year earlier to about $121 million. Sales, however, remained the same at $2.13 billion. Profit margins for this group thus averaged 5.7%, down from 7.4% in fourth-quarter 1984.

For the 13 larger chemical companies, combined earnings declined 27% to about $323 million, and composite sales increased 3% to $12.3 billion. Profit margins for the group were extremely low, however, averaging 2.6% in 1985's fourth quarter, compared with 3.7% in 1984's fourth quarter.

For full-year 1985, total earnings for the 26 firms decreased 22% from 1984 to $2.43 billion, and composite sales remained the same at $56.5 billion. Profit margins fell to an average 4.3% from 5.5% in 1984. For the 13 larger companies, combined earnings fell 24% from 1984 to $1.91 billion, and combined sales remained unchanged at $47.9 billion. Thus profit margins dropped to 4.0% last year from 5.2% in 1984. For the smaller 13 firms, 1985 composite earnings fell 14% to $525 million, and total sales declined 2% to $8.63 billion. That gave an average profit margin of 6.1% for these firms in 1985, down from 7.0% in 1984.

Looked at another way, for the last quarter of 1985, 13 of the firms posted declines in earnings and three, excluding Dow, for which it is impossible to tell, reported deficits. That's some improvement from the third quarter, when 19 of the companies posted earnings drops and two showed losses, giving some

Petrochemicals profits improve in fourth quarter

Chemical results from large oil firms may offer some hope for the chemical industry in general. These earnings, coming largely from long-suffering commodity petrochemicals, show that there finally may be some pickup where a lot is needed.

In some ways, petrochemicals magnify the problems of the chemical industry. They have been plagued by extremely weak prices; increased foreign competition from newly started up plants in the Mideast, Canada, and other parts of the world and from imported finished goods such as plastics and textiles; and have been suffering through a spate of overcapacity that is still leading to plant shutdowns.

However, the fourth quarter looks better than any past quarter for some time. Chemical net earnings at five oil firms finally started to move up. Net earnings for the five totaled $162 million, up an average of 25% from the year before. This increase came from three of the five companies. Amoco's earnings were up 7%; Shell's rocketed 106%; and Mobil's climbed from a deficit of $23 million in fourth-quarter 1984 to a profit of $19 million in fourth-quarter 1985.

Exxon posted a 19% decline to $67 million, and Texaco posted a $2 million loss, compared to profits of $12 million in fourth-quarter 1984. Exxon says it had higher sales volumes, but they did not fully offset higher costs and lower margins.

For Amoco, however, higher sales volumes for most chemical and polymer products more than offset lower product margins. In addition, according to the company, results for synthetic fabrics and fibers and other plastics products generally continued a strong performance begun earlier in the year.

The improvement in the fourth quarter, however, was nowhere near enough to save full-year results. For all of 1985, total chemical net earnings for the five companies declined 29% from 1984 to $593 million, as all of the firms experienced drops with the exception of Mobil, whose chemical earnings rose 59% to $54 million.

At Shell, whose earnings fell 27%, chairman John F. Bookout says, "The earnings decline for the full year was due primarily to severely depressed margins in base chemicals—particularly olefins."

EARNINGS ON CHEMICAL OPERATIONS

	Fourth quarter			Full year		
$ Millions	1985	1984	% change	1985	1984	% change
Amoco	$ 45	$ 42	7%	$195	$211	−8%
Exxon	67	83	−19	243	430	−43
Mobil	19	−23	def	54	34	59
Shell	33	16	106	96	132	−27
Texaco	−2	12	def	5	25	−80
TOTAL	$162	$130	25%	$593	$832	−29%

def = deficit.

Earnings declined for most oil and gas and diversified firms

	% chemical sales	FOURTH-QUARTER 1985						FULL-YEAR 1985					
		Sales	Earnings[a]	Change from 1984		Profit margin[b]		Sales	Earnings[a]	Change from 1984		Profit margin[b]	
		($ millions)		Sales	Earnings	1985	1984	($ millions)		Sales	Earnings	1985	1984
OIL AND GAS COMPANIES													
American Petrofina	15%	$ 657.7	$ −39.4	24%	def	def	3.2%	$ 2,421.6	$ 13.0	13%	−71%	0.5%	2.1%
Amoco	10	7,372.0	390.0	6	−16%	5.3%	6.7	28,850.0	1953.0	−1	−11	6.8	7.5
Chevron	4	10,700.0	380.0	−20	−12	3.6	3.3	45,300.0	1445.0	−4	−6	3.2	3.2
Diamond Shamrock	21	1,063.4	47.8	−2	−16	4.5	5.3	4,101.8	205.6	−9	−15	5.0	5.4
Exxon	7	24,557.0	1488.0	0	−19	6.1	7.4	97,288.0	5403.0	4	−3	5.6	6.0
HNG/Internorth	5	3,240.1	53.3	8	−29	1.6	2.5	10,252.8	218.5	40	−24	2.1	3.9
Kerr-McGee	13	899.5	27.6	0	−48	3.1	5.9	3,344.5	136.5	−5	−11	4.1	4.3
Mobil	4	16,337.0	425.0	1	71	2.6	1.5	60,378.0	1548.0	0	22	2.6	2.1
Occidental Petroleum	7	3,775.9	33.7	−6	−82	0.9	4.6	14,534.4	455.0	−7	−20	3.1	3.6
Shell Oil	16	5,786.0	652.0	6	12	11.3	10.6	21,560.0	1650.0	−1	−7	7.7	8.1
Standard Oil (Ohio)	5	3,688.0	379.0	15	11	10.3	10.6	13,818.0	1460.0	13	−5	10.6	12.6
Sun Co.	3	4,400.0	136.0	15	0	3.1	3.6	15,080.0	524.0	−2	−3	3.5	3.5
Texaco	2	12,500.0	307.0	4	44	2.5	1.8	47,500.0	1233.0	−1	15	2.6	2.2
Unocal (Union Oil)	10	2,920.0	17.3	−2	−89	0.6	5.2	11,640.0	532.0	1	−24	4.6	6.1
Williams Cos.	22	816.0	10.7	−6	6	1.3	1.2	3,139.6	31.6	−7	−77	1.0	4.1
DIVERSIFIED MANUFACTURERS													
Allied	24	2,615.0	69.0	14	−30	2.6	4.3	9,115.0	443.0	−4	−9	4.9	5.2
Aluminum Co. of America	4	1,226.3	23.7	−12	30	1.9	1.3	5,206.5	140.3	−10	−51	2.7	5.0
Borden	28	1,250.0	55.7	9	21	4.5	4.0	4,720.0	193.8	3	6	4.1	4.0
Borg-Warner	21	1,027.9	62.7	4	11	6.1	5.8	3,963.6	178.5	1	−13	4.5	5.3
Du Pont	38	7,620.0	377.0	2	23	4.9	4.1	29,483.0	1337.0	−4	−7	4.5	4.7
Engelhard	23	675.3	11.1	5	−37	1.6	2.8	2,263.7	58.9	−10	−43	2.6	4.1
FMC	39	856.0	39.1	1	−21	4.6	5.8	3,260.9	196.6	46	−13	6.0	10.1
GAF	56	174.2	12.2	5	26	7.0	5.8	732.0	54.3	0	32	7.4	5.6
General Electric	7	8,730.0	660.0	9	1	7.6	8.2	28,290.0	2336.0	1	2	8.3	8.2
Georgia-Pacific	10	1,590.0	33.0	−10	−48	2.1	3.6	6,716.0	207.0	1	−18	3.1	3.8
Kaiser Aluminum	18	512.5	11.4	−2	192	2.2	0.7	2,028.6	−54.0	−7	def	def	def
Koppers	0	360.9	−34.5	−5	def	def	1.0	1,400.2	−30.0	1	def	def	1.7
Eli Lilly	23	817.1	124.5	5	6	15.2	15.1	3,270.6	517.6	5	6	15.8	15.8
3M	15	1,963.0	148.0	4	−11	7.5	8.9	7,846.0	664.0	2	−9	8.5	9.5
Merck	17	958.0	134.4	0	16	14.0	12.0	3,547.5	539.9	0	10	15.2	13.8
NL Industries	37	377.1	7.6	6	13	2.0	1.9	1,423.0	23.9	5	32	1.7	1.3
Pfizer	10	1,057.9	139.3	9	7	13.2	13.4	4,042.5	579.7	4	13	14.3	13.2
Tyler	33	218.9	0.7	−1	−90	0.3	3.0	912.4	15.4	−2	−47	1.7	3.1
Upjohn	13	514.0	50.3	14	15	9.8	9.7	2,008.5	203.2	6	7	10.1	10.0
U.S. Steel	6	4,700.0	57.0	0	97	1.2	0.6	19,300.0	409.0	1	−17	2.1	2.6
Vulcan Materials	33	239.0	14.3	−5	−22	6.0	7.3	971.8	79.6	0	2	8.2	8.1

a Earnings from continuing operations excluding significant extraordinary and nonrecurring items. **b** After-tax earnings as a percentage of sales. **def** = deficit.

hope perhaps of the beginnings of a turnaround.

Most chemical executives, in reporting earnings, chose to speak of the full-year 1985 rather than just the fourth quarter. One exception was C. Robert Powell, chairman of Reichhold Chemicals, which posted a loss in the quarter. Powell says, "We are disappointed by our 1985 fourth-quarter performance. Gross profit was off slightly owing to soft demand resulting in higher manufacturing expenses and higher raw material-to-selling price ratios in portions of our domestic businesses. These two factors were only partially offset by the gross profit contributions of our acquired businesses. The gross profit decline, coupled with higher operating expenses companywide, primarily in the acquired businesses, resulted in a fourth-quarter operating loss."

At National Distillers & Chemical, which reported a slight earnings improvement in the fourth quarter, chairman Drummond C. Bell says of the three-month period, "Petrochemical results were disappointing, improving only slightly over the depressed 1984 quarter. However, oleochemical earnings continued to increase steadily."

Dow president and chief executive officer Paul F. Oreffice says that the company "saw stronger sales volume in the fourth quarter and price increases announced near year's end have held on most products. I am optimistic that this is an early indicator of an improved pricing climate in the months ahead."

However, the strong dollar came in for its share of the blame. American Cyanamid chairman George J. Sella Jr. states that the company's earnings decline came from the strong dollar, which affected international operations and resulted in lower prices for fertilizers and chemicals in the U.S.

Monsanto's chairman and chief executive officer Richard J. Mahoney comments: "Our chemicals, plastics, and fibers businesses suffered from a strong dollar in 1985. In spite of a reduction in the dollar's value during much of the year, import competition experienced by our customer industries as well as ourselves, limited volume demand and kept significant restraints on pricing flexibility and profit margins." But he continues, "We expect some benefits from a weaker dollar and reduced interest rates to materialize by mid-year 1986. Additionally, the benefits of our massive corporate restructuring during 1985 should improve the outlook for the chemicals, plastics, and fibers businesses in 1986 and beyond."

This optimistic attitude was quite common in the industry at the end of the fourth quarter, and at least some of the optimism was pinned on restructuring programs that took place last year. Dow's Oreffice says of that company's restructuring, especially in basic chemicals and plastics, "We expect significant near-term profit improvement in these businesses. Dow today is more trim and efficient and is well poised to maximize growth in the years ahead."

For Du Pont, chairman Edward G. Jefferson says, "Results for 1985 reflected weaker demand for chemical and specialty products, lower prices in many businesses, and continued global competitiveness problems resulting from the abnormal strength of the U.S. dollar. In the past year we took additional steps to improve our competitive position through further productivity improvements, business restructurings, stronger marketing efforts, and introduction of new products." He adds, "We enter 1986 in a stronger competitive position. Du Pont's cash flow from operations remains excellent, and major restructuring efforts are behind us. We have strong expectations for many new products under development and for investments we have made in attractive markets." □

Biotechnology firms still difficult to evaluate

David Webber, C&EN New York

As the biotechnology-based industry moves steadily closer to a truly commercial phase, it is rapidly assuming a clearer and clearer profile. A burgeoning of product developments and business arrangements is imparting depth and color to what was, just a few years ago, little more distinct than a connect-the-dots picture.

But representatives of small biotechnology companies, large chemical and pharmaceutical corporations, and the investment community who met earlier this month at the Industrial Biotechnology Association's annual biotechnology financial issues meeting in Fort Lauderdale agree that there is still a long way to go before it is possible to sketch in the ultimate shape of biotechnology-based commercial activity. And the investment analysts, who must attempt to place a value on the individual players in the biotechnology field, agree that they are still a way from a fully satisfactory method with which to differentiate the promise of the small firms. Those issues and others were discussed in talks ranging from biotechnology finances to strategic planning to merger and acquisition possibilities to the international scene.

The investment community's perspective on the small biotechnology companies will cycle between concern over possible pitfalls and belief in their promise over the next half year, says Linda I. Miller, assistant vice president at Paine Webber. During the second half of the year, she says, investors will begin to base their decisions more on actual payoffs in the form of new product introductions, good results from clinical tests, better financial statements, and continued evidence of corporate interest in biotechnology acquisitions.

She and other analysts agree that the key events fueling the rise in biotechnology stock prices that has surged unchecked since last September were two acquisition agreements made in third-quarter 1985—Eli Lilly/Hybritech and Bristol-Myers/Genetic Systems—along with the Food & Drug Administration's approval of Genentech's human growth hormone, a general improvement of financial performance across the industry, and a more positive patent picture.

According to Miller, the acquisitions were the triggering event: They made biotechnology's commercial promise credible again by showing that there was a "safety net" of technology value to an investment, whether a company managed to develop a line of major products or not. The growth hormone approval, she argues, "catapulted other products into the same favorable framework."

In the patent area, she points out, broad blocking patents, which could slow the general movement to commercialization, lost some of their teeth. Hybritech's failure to prove patent infringement against Monoclonal Antibodies was taken as a case in point (C&EN, Sept. 9, 1985, page 6). At the same time, she notes, product-related patents, essential to the security of the small companies, gained ground.

However ascendant the theme of promise has been since last fall, Miller believes investors will be increasingly concerned with payoff as the year wears on. For one thing, the stock market's current cumulative valuation of the biotechnology companies, now in the $4 billion to $5 billion range, can be supported only by an accelerating number of tangible positive developments, she contends.

In addition, she expects that the increase in investment opportunities in the biotechnology area will force investors to be more selective.

he says, many of the issues that preoccupy the small biotechnology firms—finances, general management, regulatory staffs, and the like—do not matter to the large company. "They will ask themselves one simple question," Fildes says: "What is this company's scientific capability?"

Potential acquirers also will base their decision on a small firm's product line, he says. Some will look for products that fit and can extend their current business areas, as Bristol-Myers did in acquiring Genetic Systems. The aim there, many agree, was to bolster Bristol's existing business in anticancer products. Others will buy to diversify into new areas. One example is the Hybritech acquisition, which gave Lilly entry into the diagnostics arena.

The small biotechnology companies must consider the possibility of being acquired from a different perspective, Fildes notes. "How can companies resist?" he asks. "Or, when should they?"

"If your object is to increase the return to your shareholders, you must ask the question of whether you should resist at all," he says. "I don't think you can resist too easily anyway. If somebody is determined to get you, there are ways to do it."

On the other hand, he says, large corporations realize that an unfriendly acquisition would not work, because the "powerhouse" of the small companies is their employees. Current wisdom holds that most of them would either not wish to work for a large corporation or would wither outside the more freewheeling climate of the small, entrepreneurial companies. "If you can't keep the people," Fildes says, "you've bought nothing." □

Drug firms dominate biotechnology patents

Although the small biotechnology companies that started up during the past decade still gain most of the publicity, it is the large, established pharmaceutical companies that continue to dominate biotechnology-related patent activity in the U.S., according to Omec International, a Washington, D.C., consulting firm. Omec's analysis of patents issued in 1985 in the biotechnology field also show U.S. corporations broadening their share of the patent picture at the expense of foreign concerns. U.S. universities, too, are gaining an increasing number of patents.

According to Omec, the U.S. Patent & Trademark Office issued a total of 1078 biotechnology-related patents in 1985, compared with 1114 in 1984 and 1018 in 1983. U.S. companies, universities, organizations, or individuals accounted for 640 of them, compared with 663 in 1984 and 562 the year before that. Of the U.S. total, 489 patents went to corporations, well up from 441 a year earlier and 400 in 1983. U.S. universities were awarded 86 of the patents, up from 1983's 68 but below the 95 in 1984. However, Omec points out, the 1985 calculation does not include patents issued to nonprofit organizations on behalf of universities. Adding those would bring the 1985 academic total to 98. The remaining portion of the U.S. total, 65, was accounted for by nonprofit groups, government agencies, and individuals. That figure has fluctuated: 127 in 1984 and 94 in 1983.

Although down from an impressive 45% of all U.S. biotechnology-related patents in 1983, the share of such patents awarded to foreign entities remained a significant 41% last year. Foreign corporations dominated the segment, winning 363 U.S. patents in 1985, compared with 371 in 1984 and 383 in 1983. Foreign universities, nonprofit organizations, government agencies, and individuals received 75 patents last year, compared with 80 the year before and 73 in 1983.

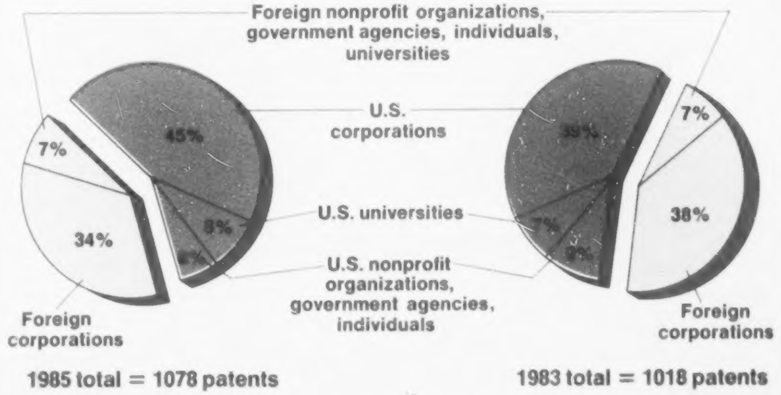
The largest number of patents went to major pharmaceutical houses. Eli Lilly led all firms with 28 last year, followed by Miles Laboratories with 19, Boehringer Mannheim with 14, Merck with 13, and Pfizer with 12. Of 32 firms receiving five or more biotechnology-related patents in 1985, only four were small biotechnology operations.

Japan continued to dominate foreign patent activity in 1985. Of the 438 U.S. biotechnology-related patents issued to foreign entities last year, 178, or 41%, went to Japan. The next closest country was West Germany with 73 patents, or 17% of the foreign total. Other countries with more than 10 patents were France with 33, the U.K. 32, Canada 20, U.S.S.R. and Soviet-bloc nations 15, the Netherlands 14, Italy 11, Sweden 11, and Switzerland 11.

The most prominent universities in the area last year were the University of California system with 14, the University of Minnesota six, Stanford six, and Cornell, MIT, and Purdue four each.

David Webber, New York

American corporations gain larger share of biotechnology-related patents issued in U.S.



Source: Omec International

Profits of Canadian Chemical Firms Surge in Fourth Quarter

However, 1985 as a whole was a tough year for four large companies, whose combined sales rose only 1.3% over 1984 and profits dropped 21%

Like a long-distance runner with a strong finishing sprint, the Canadian chemical industry ended 1985 with vastly improved sales and profits in the fourth quarter. But that still wasn't enough to make 1985 a year the industry would want to relive.

Canada's national energy program, which raised feedstock costs for Canadian chemical companies, is gone—replaced by more-market-oriented energy pricing policies. But the industry still had to bear the brunt of NEP during most of 1985. Meanwhile, for many chemical products, intense competition and overcapacity in the industry's all-important international markets made 1985 a tough year.

The combined results of four large publicly traded Canadian chemical companies tell the story. In fourth-quarter 1985, those firms (C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada) boosted sales 8.8% (based on Canadian currency) from fourth-quarter 1984 to \$638 million (\$1.00 = 1.40 Canadian dollars at the end of December 1985). Profits, however, rose a hefty 60% to \$17.2 million, and profit margins (net income as a percentage of sales) improved to 2.7% from 1.8% in fourth-quarter 1984.

But one quarter does not make a full year. For all of 1985, the combined results of the four companies show sales inching up only 1.3% from 1984 to \$2.48 billion and profits dropping a worrisome 21% to \$51.7 million. Profit margins, naturally, felt the impact, dropping to 2.1% from 2.7% in 1984.

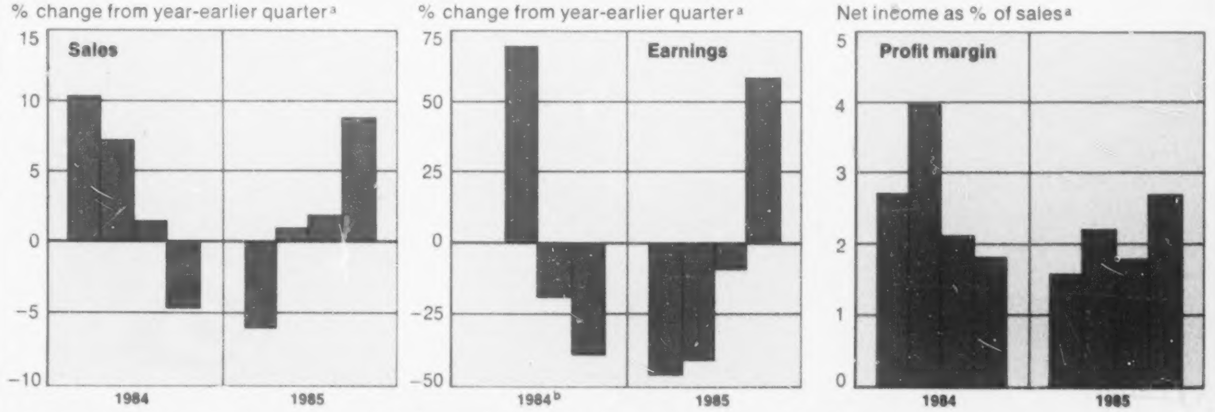
Admittedly, the four companies have different product lines and different business philosophies. No one of them can be said to represent a less-than-homogeneous chemical industry. Nevertheless, based on financial results available from a scattering of other Canadian firms with chemical operations, the combined results of the Big Four, with their good fourth quarter and poor full year, reflect fairly accurately the kind of year that 1985 was for the entire Canadian chemical industry.

Of the Big Four chemical companies, only Celanese Canada had an exceptionally profitable year. Although full-year sales were down 4.1% in 1985 to \$265 million, profits were up a staggering 61% to \$9.0 million, with most of the gain coming in the third and fourth quarters.

In the fourth quarter, for instance, Celanese Canada's net income rose 373%, following a 375% gain in the third quarter—even though fourth-quarter sales increased only 0.8% over fourth-quarter 1984.

Robert J. St. Jacques, executive vice president of Celanese Canada, says that quarterly earnings in the fourth quarter were the company's best since the second quarter of 1981.

Chemical industry sales, earnings, and profit margins are on the rebound



a Based on combined Canadian-currency results of C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada.

b No first-quarter point because of deficit in first-quarter 1983.

He credits the firm's three-year restructuring and reorganization program for much of the improvement. Improved exchange rates for European currencies against the Canadian dollar also helped.

Last year the remaining Big Four companies fared far less well than Celanese Canada. Union Carbide Canada, for instance, saw its net income before extraordinary items plunge 97% despite a 283% jump in the fourth quarter. For the entire year, Carbide Canada essentially broke even on operations, earning $100,000 despite a 5.8% drop in sales to $465 million. But an extraordinary charge related to the company's planned sale of its polyethylene business saddled it with a net loss of $64 million for the year. The firm has included polyethylene sales in its 1985 results for comparison purposes, but this business will be reclassified as "discontinued operations" in its 1985 annual report.

Carbide Canada chairman W. Norman Kissick says the company's plastics, chemicals, gases, and carbon businesses improved in the fourth quarter. Meanwhile, heavily discounted "gray-market" imports from Europe have put price pressure on the firm's battery operations.

Carbide Canada's consumer product businesses will be sold early this year—part of Union Carbide Corp.'s decision to divest its worldwide consumer operations. Although that will lower Carbide Canada's sales, Kissick expects earnings to improve appreciably.

Du Pont Canada also followed the good-fourth-quarter, poor-year pattern. Fourth-quarter earnings from operations increased 37% for Du Pont, whereas yearly earnings of $14.7 million were down 50% on 1.3% higher sales of $847 million. But Du Pont shed its investment in Petrosar Ltd. and closed a lead alkyl plant last year. Those extraordinary charges gave the company a net loss of $18.5 million in 1985.

C-I-L was the one company among the Big Four whose fourth-quarter income dropped last year despite a 15% sales gain. For the year, C-I-L's sales advanced 7.5% to $902 million, but net income from operations increased only 2.6% to $27.9 million. The company also had to shoulder a $15 million extraordinary charge by closing its phosphoric acid and phosphate fertilizer facilities at Courtright, Ont.

The diversified C-I-L increased sales volume for many products, especially ammonia from its expanded Courtright plant. However, intense competition and overcapacity continued to plague prices for fertilizer and explosives. The company hopes that a new agreement, under which it will obtain lower-cost feedstock for its Courtright ammonia unit, will improve its competitive position in North American nitrogen products markets.

Earl Anderson, New York

For Canadian firms, a strong fourth quarter but poor year

$ Millions[a]	Net sales	Change from 1984[b]	Net income	Change from 1984[b]	Profit margin[c] 1985	Profit margin[c] 1984
FOURTH-QUARTER 1985						
C-I-L	$224.9	15.0%	$ 3.6	−29.9%	1.6%	2.6%
Celanese Canada	74.3	0.8	3.7	372.7	5.0	1.1
Du Pont Canada	213.1	5.4	5.0	37.3	2.4	1.8
Union Carbide Canada	126.0	9.3	4.9	283.3	3.9	1.1
TOTAL	**$638.3**	**8.8%**	**$17.2**	**59.6%**	**2.7%**	**1.8%**
FULL-YEAR 1985						
C-I-L	$ 902.5	7.5%	$27.9	2.6%	3.1%	3.2%
Celanese Canada	265.4	−4.1	9.0	61.5	3.4	2.0
Du Pont Canada	847.0	1.3	14.7	−50.0	1.7	3.5
Union Carbide Canada	464.8	−5.8	0.1	−96.5	neg	0.8
TOTAL	**$2479.7**	**1.3%**	**$51.7**	**−21.3%**	**2.1%**	**2.7%**

a $1.00 = 1.40 Canadian dollars. **b** Based on Canadian currency. **c** Net income as percentage of sales. **neg** = negligible.

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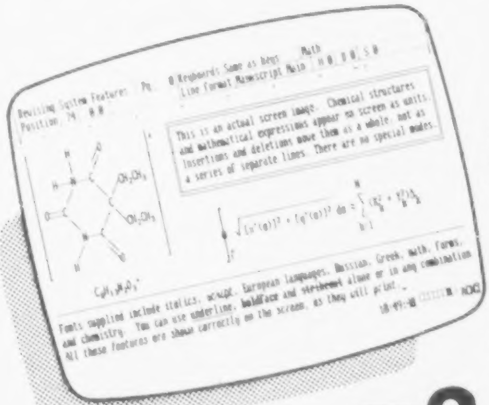

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corporate. "There's real potential," reports Sheldon Krimsky of the Tufts University department of urban and environmental studies, "of the Strategic Defense Initiative tearing the campuses apart. Lines are being drawn. Friendships are being tested. There are clauses in some contracts I know about that say that if classified results do come out, the researcher must continue to do the research under classified status. For the first time since the 1950s, faculty meetings at which corporate and defense research funding are discussed are closed to nonparticipating members of the university community. It isn't that mass concern is sweeping academia—indeed, if any reaction is prevalent, it is that of euphoria over the government's intention to fund interdisciplinary research centers at the major research universities."

However, there are local concerns. Studies he did for the Office of Technology Assessment, Krimsky says, reveal that the people living near academic communities are showing less confidence that the government is protecting them from classified research being done in university laboratories. "We see local communities frustrated by what they see as potential risks that are not handled by the scientific community, like the Monterey, Calif., board of supervisors saying no to the release of organisms in the environment. There is no confidence that the federal government is interested in really protecting the public."

So the academy meeting, most of it closed to the press, will provide a lot to talk and haggle over. The scientific establishment prizes objectivity and is beginning to show some skepticism over the rosy picture the "new science policy" represents, such as the phenomenon of the Office of Science & Technology Policy calling the Engineering Research Centers hugely successful before any have begun functioning.

A survey of the new relationships by social scientists Dorothy Nelkin of Cornell University and Richard Nelson of Yale sets the new cautionary tone. The assessment was done for the Academy Government-University-Industry-Research Roundtable. "We are of two minds regarding the meaning of this rosy picture," they say. "On the one hand, it is comforting. On the other, we talked only to people who are benefiting from these agreements. We found it difficult to get beneath the promotional tone of the involved corporate and university scientists to find out what was really going on.

"To the extent that these new relationships are experiments," Nelkin and Nelson conclude, "they may be experiments that strongly resist negative evaluation."

How the academy meeting evaluates the situation, then, should make interesting theater. Krimsky, Nelkin, and other social scientists engaged in research on the policy issues the academy will be dealing with report that their field, too, is being starved out of existence by federal cuts. □

Budgets for regulatory agencies gain little

For some years big budget increases haven't been in the cards for the federal regulatory agencies that in one way or another affect the chemical industry. And with the Administration intent on meeting the fiscal 1987 mandatory deficit target of $144 billion set in the Balanced Budget & Emergency Deficit Control Act of 1985, fiscal 1987 will be no exception.

In the Administration's fiscal 1987 budget proposal, a number of the agencies, such as the Environmental Protection Agency, Occupational Safety & Health Administration, and Food & Drug Administration, are slated for funding increases above fiscal 1986 levels. But for some agencies there is an increase only because fiscal 1986 funding levels were reduced 4.3% from Congressionally set levels by the automatic cuts mandated by the balanced budget act.

EPA's fiscal 1987 regulatory budget is slated to rise 8% to $2.2 billion. Most of that increase is accounted for by a 22% rise to $1.0 billion in funding for the Superfund hazardous waste site cleanup program. (That request is based on the Administration's proposed $5 billion, five-year reauthorization of the program. The actual amount is likely to be much higher if the House and Senate finally agree on how to finance the expanded Superfund program they both advocate.)

Also increased at EPA are programs aimed at curbing future hazardous waste problems, up 10% to $206 million, and ensuring the health and environmental safety of pesticides, up 2% to $56 million. In the pesticide safety area, EPA will allocate some $22 million for the generic chemical review program.

The toxic substances program, on the other hand, is on a steep downward slide, falling 45% to $57 million. A large portion of the decrease, $44 million, reflects EPA's decision not to request financial assistance for state and local asbestos abatement programs. However, EPA has requested a 65% increase, to about $7 million, for its radon assessment and monitoring program.

At OSHA, funding is slated to

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EPA's regulatory budget would rise 8%

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986-87
Superfund	$1050.0	$ 861.3	$ 620.0	22%
Management and support	291.3	271.0	294.5	7
Water quality	193.4	217.8	228.4	−11
Air	176.0	180.0	168.2	−2
Hazardous waste	205.6	186.1	145.3	10
Drinking water	61.6	63.1	67.2	−2
Toxic substances	56.9	102.3	59.5	−44
Pesticides	56.2	55.0	57.2	2
Interdisciplinary	28.5	29.2	29.7	−2
Radiation	59.4	59.6	11.1	—
TOTAL	**$2178.9**	**$2025.4**	**$1681.1**	**8%**

a Estimate. b Actual. **Note:** Obligations. **Source:** Environmental Protection Agency

. . . OSHA's just 4% . . .

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986-87
Enforcement	**$145.1**	**$139.7**	**$139.4**	**4%**
Federal	90.2	86.7	86.4	4
State	54.9	53.0	53.0	4
Compliance assistance	**36.0**	**35.2**	**36.2**	**2**
Safety and health statistics	**18.6**	**18.0**	**21.0**	**3**
Technical support	**14.7**	**13.5**	**12.3**	**9**
Safety and health standards	**6.0**	**5.8**	**5.5**	**3**
Administration	**5.4**	**5.3**	**5.1**	**2**
TOTAL	**$225.8**	**$217.5**	**$219.5**	**4%**

a Estimate. b Actual. **Note:** Obligations. **Source:** Office of Management & Budget

. . . and FDA's a scant 1%

$ Millions	1987[a]	1986[a]	1985[b]	% change 1986-87
Drugs	$154.4	$159.3	$154.4	−3%
Foods	117.8	114.7	110.5	3
Devices and radiological products	69.4	68.5	67.3	1
Program management	57.8	55.3	58.6	4
National Center for Toxicological Research	22.7	22.3	22.1	2
Facilities	1.4	—	—	—
TOTAL	**$423.5**	**$420.1**	**$412.9**	**1%**

a Estimate. b Actual. **Note:** Obligations. **Source:** Office of Management & Budget

increase just 4% from fiscal 1986 to $226 million, the same level it would have been in fiscal 1986 without the automatic budget cut. OSHA says it will issue five health standards in fiscal 1987, up from four this year; increase its number of inspections from 65,000 to 71,400; and decrease its number of consultation visits from 31,650 to 30,600.

FDA's proposed budget is up just 1% to $423 million, and personnel, expected to be down 300 this year, will be down another 200 in fiscal 1987. The Consumer Product Safety Commission's efforts to protect the public from hazardous products will proceed with 8% less funding at $33.4 million.

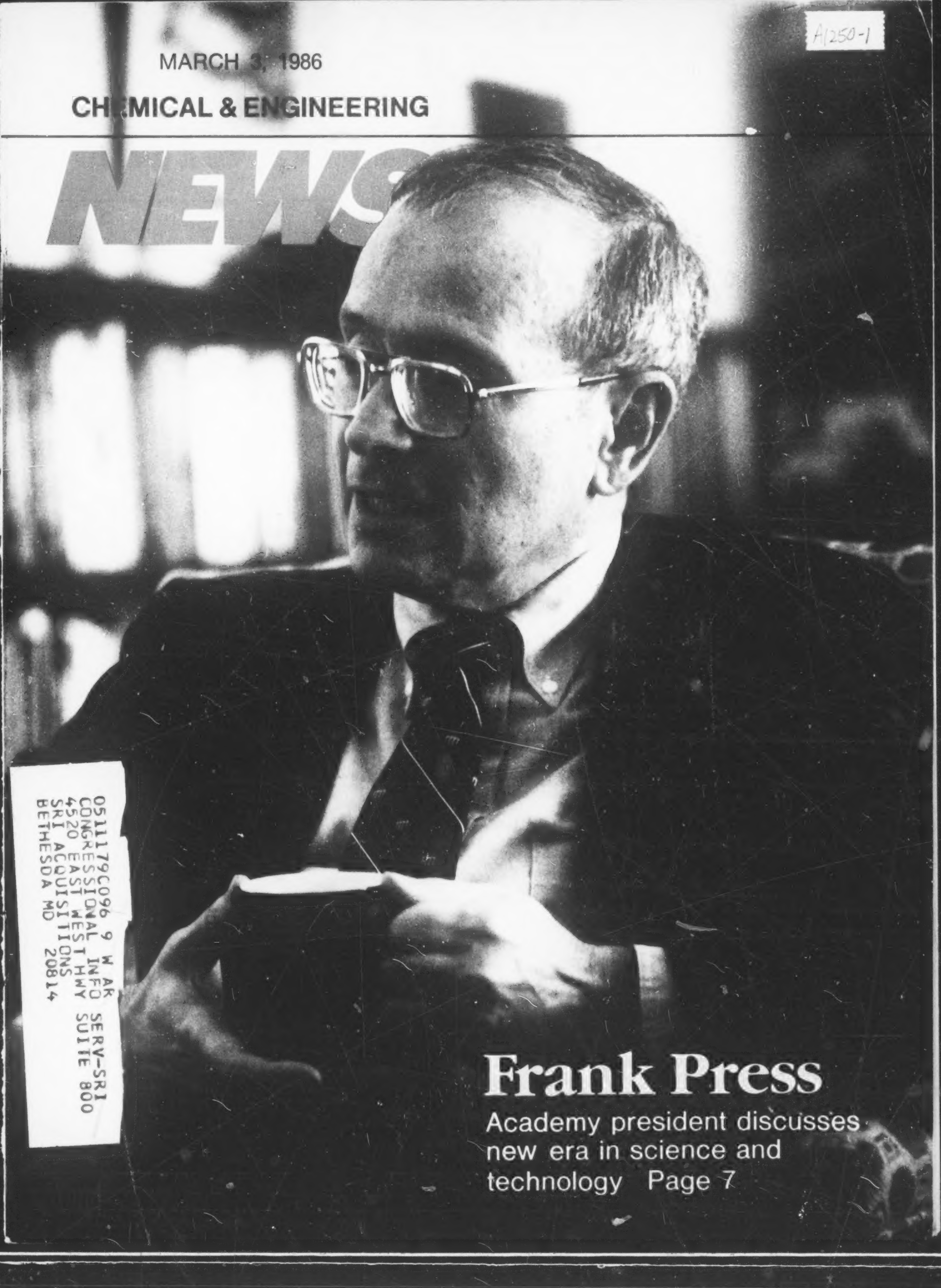
In the legal area, funding for the Justice Department's environmental enforcement activities would rise 2% to slightly more than $23 million, and funding for the antitrust division is slated to increase 4% to $46 million. Funding for the Federal Trade Commission would be held essentially constant at $69 million. On the opposite end of the scale, government support for the Patent & Trademark Office would rise almost 30% to $111 million. However, processing fees collected by PTO are expected to be down 7% in fiscal 1987 to $142 million, so its total budget would be up only 6% to $244 million.

Janice Long, Washington

A1250-1

MARCH 3, 1986

CHEMICAL & ENGINEERING NEWS



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Academy president discusses new era in science and technology Page 7

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NEWS

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MARCH 3, 1986

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Cover: Photo by C&EN's Ernest L. Carpenter

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U.S. Drug Firms' Profits Climbed 12% in Fourth Quarter

Weaker U.S. dollar helped sales increase 11%; profitability edged up slightly to 11.5% from a year earlier

David Webber, C&EN New York

The pharmaceutical industry's most intransigent problem over the past few years has been the waxing strength of the U.S. dollar. Now, through international efforts, the value of the dollar against other major currencies has waned somewhat. Though still holding down U.S. drug house earnings (most American pharmaceutical producers typically record a large share of their sales overseas), exchange rates have become less overwhelming. The change helped sales revenues of most large pharmaceutical companies grow strongly in the fourth quarter of 1985.

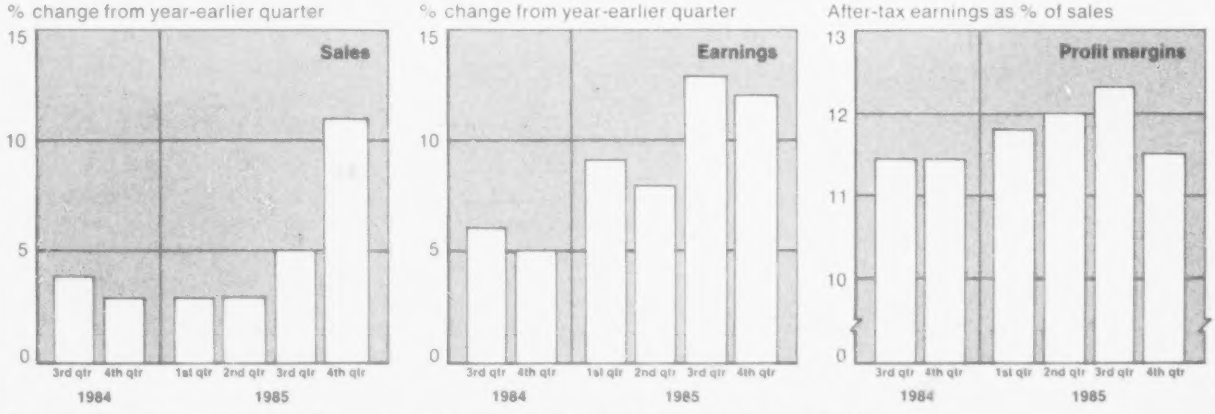
For a group of 16 major pharmaceutical companies, sales increased a composite 11% in fourth-quarter 1985 compared to the equivalent period a year earlier. The sharp increase marked the first time the group's combined revenues had risen by a double-digit percentage in several quarters. On the same basis, composite earnings from operations for the group climbed 12% from fourth-quarter 1984. The 16 companies' combined profit margin (after-tax earnings as a percentage of sales) edged up to 11.5% from 11.4% in the same quarter the year before.

For all of 1985, the group's composite sales total climbed 5% from 1984. Earnings from operations were up 10%, allowing profitability to jump to 12.0% from 11.5% in full-year 1984.

During the fourth quarter, half of the 16 companies recorded double-digit increases in sales, whereas only one firm reported a decrease in revenues. Results were equally consistent in terms of net income. Eleven companies in the group reported growth of 10% or more in earnings; only two suffered decreases, and those were only 2% each compared to fourth-quarter 1984. No company in the group lost money on operations in the final quarter of 1985.

At most companies, pharmaceutical segments performed well. More mixed results were recorded by the hospital supply and medical devices business units. Those firms with specialty chemical and agricultural chemical businesses had problems similar to those encountered by chemical companies in those areas. Most personal care and household products segments recorded a successful quarter.

One of the more notable gains in the quarter was recorded by Baxter Travenol, which raised net income 57% on a sales increase of 82%. These results factor out a $29 million after-tax charge to earnings to cover the costs of asset and staff consolidations associated with the November acquisition of American Hospital Supply while including sales contributed over the final six weeks of the year by the new unit. Nevertheless, Baxter Travenol sales rose across the board: up 13% in the par-



Pharmaceutical industry 1985 fourth-quarter results

Note: All sales, earnings, and profit-margin statistics are based on combined results of the 16 companies listed on page 15.

Pharmaceutical profit margin rose in fourth quarter

	FOURTH-QUARTER 1985						FULL-YEAR 1985					
	Sales	Earnings[a]	Change from 1984		Profit margin[b]		Sales	Earnings[a]	Change from 1984		Profit margin[b]	
	($ millions)		Sales	Earnings	1985	1984	($ millions)		Sales	Earnings	1985	1984
Abbott Labs	$ 954.4	$141.4	12%	15%	14.8%	14.5%	$3360.3	$465.3	8%	16%	13.8%	13.0%
American Home Products	1153.9	183.7	4	10	15.9	15.1	4684.7	717.1	4	9	15.3	14.6
Avon Products	787.4	62.9	10	−2	8.0	9.0	2470.1	128.2	−5	−16	5.2	5.8
Baxter Travenol	839.0	36.0	82	57	4.3	5.0	2355.0	166.0	31	14	7.0	8.1
Becton Dickinson	265.4	17.5	5	21	6.6	5.7	1156.1	91.1	3	39	7.9	5.8
Bristol-Myers	1109.2	130.9	10	11	11.8	11.6	4444.0	531.4	6	12	12.0	11.3
Lilly	817.1	124.5	5	6	15.2	15.1	3270.6	517.6	5	6	15.8	15.8
Merck	958.0	134.4	0	16	14.0	12.0	3547.5	539.9	0	10	15.2	13.8
Pfizer	1057.9	139.3	9	7	13.2	13.4	4024.5	579.7	4	13	14.4	13.2
A. H. Robins	186.1	16.8	12	132	9.0	4.4	706.1	61.4	12	124	8.7	4.3
Schering-Plough	488.4	43.3	9	15	8.9	8.4	1927.1	192.6	3	9	10.0	9.5
SmithKline Beckman	895.2	129.6	17	7	14.5	15.8	3256.6	514.4	10	3	15.8	17.0
Squibb	591.3	59.5	13	19	10.1	9.5	2041.7	226.6	8	15	11.1	10.5
Sterling Drug	468.2	43.2	9	24	9.2	8.1	1753.7	153.3	2	8	8.7	8.2
Upjohn	514.2	50.3	14	15	9.8	9.7	2008.5	203.2	6	7	10.1	10.0
Warner-Lambert	765.7	50.4	−4	−2	6.6	6.4	3200.1	237.7	1	6	7.4	7.1

a Excludes significant extraordinary and nonrecurring items. **b** After-tax earnings as a percentage of sales.

enteral therapy segment; up 8% in blood therapy; up 10% in renal and urological therapy; and up 33% in other medical products and services.

Becton Dickinson also peformed well in the fourth quarter, with a 21% rise in net income on a 5% increase in sales. Revenues rose for both major segments: medical products, up 4% to $133 million, and diagnostic products, up 17% to $98 million. Sales of nonhealth care products declined 18% in the quarter, but that was primarily the result of the divestiture of the company's Digitran division.

At Upjohn, earnings jumped 15% on a 14% increase in sales. The company's sales of human health care products and services increased 18% in the fourth quarter. This was largely due to record sales by Xanax, a central nervous system disorder agent that is now Upjohn's leading product, and good performance by other drug products, and despite lower revenues from Motrin, pricing for which has declined to answer competition from over-the-counter ibuprofen products. Sales of agricultural products declined 4%. The company says agronomic seed demand was strong in the U.S., Argentina, and Mexico, but prices were significantly lower in the U.S.

Squibb recorded record sales and earnings for both fourth-quarter and full-year 1985. Over the course of the year, the pharmaceutical products group performed strongly, with a 10% increase in worldwide sales. At the same time, however, the medical products group reported a sharp decline in profits despite a 4% increase in sales for the year. The chief cause was the company's inability to maintain product development schedules in two areas, but those problems have now been solved, the company says. Squibb's personal care group, Charles of the Ritz, did well. Sales rose 8% globally, resulting in a 9% increase in pretax profits.

"The marked improvement in recent years in the ratio of profit from operations to sales—17.4% in 1985 compared with 9.9% in 1981—is a key indicator of better earnings quality," comments Richard M. Furlaud, chairman and chief executive officer. "This was achieved despite an increase in R&D expenditures of 74% over the 1981 level." In 1985, Squibb spent $166 million on research, up 10% from 1984 outlays.

Sterling Drug raised its net income 24% in the fourth quarter on a 9% sales increase. At the end of 1985, the company decided to divest its Hilton-Davis chemical business and sold that unit's optical brighteners component. This was part of the company's strategy to concentrate on its core businesses of prescription medicines, proprietary medicines, and household and consumer products. Those segments performed well in the final quarter. Sales of pharmaceutical specialties rose 2% and increased 11% for proprietary products and 24% for household and consumer products.

For the full year, Sterling's net income rose 8% on a 2% sales increase. Though pharmaceutical specialties sales were flat, revenues from proprietary products moved up 3%. Sales of household and consumer products, the largest single domestic segment, jumped 10% in 1985 compared to 1984.

At Eli Lilly, earnings rose 6% and sales 5% in both fourth-quarter 1985 and full-year 1985, compared to their respective year-earlier periods. For the full year, Lilly's human health businesses prospered: Pharmaceutical products sales increased 7%, led by oral antibiotics and human insulin products, and medical instrument systems sales rose 20%. Sales of agricultural chemical and animal health products, on the other hand, declined 6% for the year. One bright note: U.S. agricultural chemical sales were up, led by strong sales for Sonalan herbicide. Lilly's cosmetics unit, Elizabeth Arden, reported record sales for the year, up 9% from their 1984 level. □

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MARCH 10, 1986

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Science Education

Crisis at precollege level is over but problems remain Page 7

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Cover: Photo by C&EN's Ward Worthy

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Productivity in the U.S. chemical industry rose nearly 6% in 1985, following a 4% rise in 1984. **Page 18**

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Perkin Medal

Peter P. Regna, who helped bring many antibiotics into commercial production, receives 1986 Perkin Medal. **Page 24**

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News Focus

The crisis in precollege science and mathematics education is over; nevertheless, many problems still must be solved. Page 12

Crisis Passes but Problems Remain For Precollege Science and Math

Dedicated individuals and groups are plugging away at the problems, not just to do a patch job, but to establish a rational national structure for such education at all precollege levels

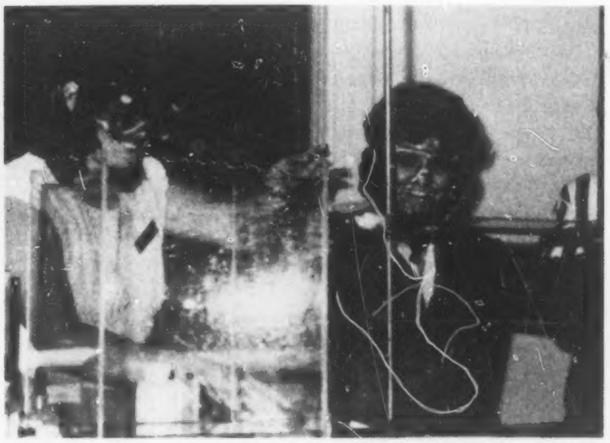
Ward Worthy, C&EN Chicago

The crisis in precollege science and mathematics education—so much in the news just four years ago—is over.

No, the problems that provoked the crisis haven't been solved. There've been a few changes for the better, but there's still plenty wrong with the way the U.S. goes about the job of teaching science and math to its kindergarten-through-12th-grade students. Nevertheless, the crisis, as measured by the benchmarks of political and media attention, has vanished.

Public concern over the crisis in precollege science and math education reached its loudest postsputnik expression in 1982. Meetings were called, speeches delivered, articles published (C&EN, July 19, 1982, page 9, for example). It was an exciting time. Study commissions were formed. Recommendations were made. A little money was dredged up from here and there. A few programs got under way. The public has a short attention span, however. The excitement soon died down. What was a clamor in 1982 has diminished to a murmur in 1986.

Crisis past, problems remain. Was all in vain? No. But that's not the right question. A crisis, by definition, doesn't drag on. A crisis (the dictionary says) is "a decisive moment" or, for a patient with a serious illness, "a turning point for better or worse." The disease that afflicts precollege science and math education had festered for years before "the patient"



High school teacher participants at Institute for Chemical Education summer workshops for chemistry teachers: (left) Tanya L. Phillips in 1984, and (above, from left) Rose McBryan and Maria Dalhoumi last year went on the critical list in 1982. Overnight recovery was not to be expected.

The question to ask, then, is not, "Has the patient been restored to good health?" but rather, "Has the patient taken a turn for the better or a turn for the worse?"

The evidence, on balance, suggests a turn for the better. It's not so much the numbers—test scores, education budgets, and such. So far, with few exceptions, the postcrisis numbers don't yet look all that much better than the precrisis numbers. However, even though the crisis atmosphere has passed, many dedicated individuals and groups are still plugging away at the problems. Encouragingly, the approach hasn't been just to do a patch job. Instead, the aim has been to establish a rational national structure for science and math education at all precollege levels.

In addition, one senses changes in climate and attitudes that bode well for the future. The scientific research community now seems more aware that the edifice of science can be no stronger than the foundation it's built upon. Consequently, science education is finally getting a little respect. The relationships between researchers and science teachers aren't quite so "us" and "them" as they used to be. Scientific societies are admitting out loud that they share the responsibility for the way that science and mathematics are taught in the public schools. Industries are expanding their support of education to include elementary and secondary schools.

What has happened in the past four years gains perspective from a brief examination of the problems that brought precollege science and math education to its 1982 crisis.

For one thing, it had become obvious that students were taking fewer science and mathematics courses than they had in former years. Also, mean scores on standard tests such as the Scholastic Achievement Test (SAT) had declined. Mean math scores, for example, dropped from 502 (out of a possible 800) in 1963 to 466 in 1980. Other measures, such as national assessments of science achievement, similarly showed declines from earlier years. A number of "international comparison" studies were made in the early 1980s. These almost uniformly alleged that U.S. students weren't doing nearly so well in science and math as their counterparts in more authoritarian parts of the world such as the U.S.S.R., Japan, and China.

According to various other surveys of the precollege scene, there were serious or critical shortages of chemistry, physics, and mathematics teachers in many states. In 1981, for example, more than half the newly hired science and math teachers were unqualified to teach their subjects, but had been hired on an emergency basis because no qualified teachers could be found. The teachers that were qualified were an aging and decreasing group. Many were demoralized by low pay, poor working conditions, and lack of support. And they were tired of getting blamed for things over which they really had no control.

Not surprisingly, few students were choosing careers as public school science or math teachers, and even fewer of the best and brightest were choosing such careers. Furthermore, university education departments were often preoccupied with turning out elementary school teachers and school administrators; responsibility for training the more discipline-oriented science and math teachers was hard to pin down.

Meanwhile, National Science Foundation support of science education, as a proportion of its total budget, had been declining fairly steadily over the years, from about 46% in fiscal 1959 to about 2% in fiscal 1982. Support for precollege science education had fared even worse, falling from 34% of the total NSF budget in 1959 to practically nothing in fiscal 1982.

That may well have been the turning point. In fact, the National Science Board (NSF's policy-making body) had already, in 1981, appointed a Commission on Precollege Education in Science, Mathematics & Technology, and had charged its members to "define a national agenda" and "develop an action plan" to address the problems in that area. The National Academy of Sciences had put the issues into even sharper focus with its May 1982 convocation on the subject (C&EN, May 24, 1982, page 39). It can be argued, however, that the NSF move to eliminate precollege support was the "Thanks, I needed that!" slap in the face that made a lot of people aware that a crisis was at hand and that something had to be done.

Indeed, a flurry of activity followed that 1982 NAS convocation. In 1983, the NSB commission presented its plan of action, "Educating Americans for the 21st Century." In a nutshell, the commission said that there should be more precollege science and math education and that it should be better (C&EN, Sept.

Teacher shortages worst for high school physics, elementary science and math

Fields	Shortage per 1000 teachers	Noncertified as % of all in field
ALL LEVELS		
All fields	1.6	3.5%
All science fields	1.7	4.1
Biology	1.7	3.8
Chemistry	1.9	4.1
Physics	4.5	5.6
Other sciences	1.4	4.0
Mathematics	1.8	4.1
SECONDARY LEVEL		
All fields	1.5	3.3
All science fields	1.4	4.1
Biology	1.7	3.8
Chemistry	1.9	4.1
Physics	4.5	5.6
Other sciences	0.8	4.0
Mathematics	1.4	4.1
ELEMENTARY LEVEL		
All fields	1.6	3.6
General science	3.9	4.0
Mathematics	4.1	4.2

Note: Data for 1984. **Source:** National Center for Educational Statistics

26, 1983, page 16). The commission also spelled out detailed recommendations as to how this should be accomplished by 1995. It also pegged the first-year costs of the program at more than $1.5 billion—and that was just the federal portion.

The American Chemical Society appointed a task force in 1983 to make an overall examination of the state of chemical education in the U.S. and to make appropriate recommendations. The task force, chaired by Peter E. Yankwich of the University of Illinois, made its report in the fall of 1984. The 70-page report, whose numerous recommendations are not easily summarized, did reflect the importance attached to the teaching of science in elementary schools.

Chemistry professor Henry A. Bent of North Carolina State University carries out demonstration at ICE summer workshop

Actions, however, not recommendations, are what solve problems. And as might be expected, the actions to date have lagged far behind the recommendations. Just the same, some things have changed.

Consider, for example, the complaint that precollege students were taking fewer science and math courses. One of the main reasons for that phenomenon was that they didn't have to take the courses at all. In the 1960s and early 1970s, school boards and other standards-setting groups reacted to the public sentiment of the times by reducing the requirements for graduation from high school as well as for admission to colleges and universities. Lately—again in reaction to public sentiment—these same groups have been moving to raise the standards again.

Even though education is still largely a local affair in the U.S., and requirements vary widely among the states, between 1980 and 1985, 30 states and the District of Columbia increased their minimum requirements for mathematics courses by at least one year. Similarly, 24 states and D.C. added at least a year's worth of science courses to their graduation requirements. Also, seven states that formerly left such matters to local boards of education since have imposed state minimums for science and math, along with other subjects.

At the same time, standard test scores, after having declined for years, have started to inch upward again. "But that's to be expected," says one observer of the education scene. "The crisis was quantified in terms of test scores. Principals' jobs were on the line. They'll admit, privately, that the word has gone out: Teach to maximize the scores."

As to the shortage of competent science and math teachers, it depends on whose numbers are looked at and whose are believed. According to head-count figures for 1984 from the National Center for Education Statistics, for example, the only really serious shortages were of high school physics teachers and elementary teachers of science and math. The proportion of noncertified teachers in those fields was a little higher than the average for all fields, but not startlingly so.

Some observers maintain that those figures are misleading, however. "There's no shortage of teachers, but there's a shortage of competence," says Bill G. Aldridge, executive director of the National Science Teachers Association. "Because of increased requirements, math and science enrollments are going up even as the general school population is declining. The overall decline produces a surplus of teachers. I'm talking, for example, about that physical education teacher they don't want to fire, so they reassign him to teach science. About a third of the classes in science are being staffed that way now."

Things will get even worse in that respect, according to Rand Corp. social scientist Linda Darling-Hammond. Enrollments in elementary and secondary schools have been declining for a decade, she says, but an early 1980s "baby boomlet" soon will cause enrollments to increase again. At the same time, the college-age population from which most teachers are drawn will continue to decline. By 1988, the number of new teachers may supply only 80% of the demand.

Meanwhile, Darling-Hammond says, "the current highly educated and experienced staff is dwindling" as a result of retirement by older teachers and desertion by younger ones. Unless reforms are made, she adds, the teacher shortage will be so critical in a few years that the least academically qualified students will become "the tenured teaching force for the next two generations of American school children."

In all this gloom about future teacher shortages, there is one bright spot. One potential source of new science and math teachers is the pool of middle-aged scientists and other quantitatively trained persons from industry or government who have chosen early retirement—or who have had it thrust upon them. Many of these people have expressed interest in second careers as teachers. Several programs to help prepare them for such careers are under way or planned.

The idea makes sense. There are a lot of talented people of all ages who would make good teachers, and who would like to be teachers. But the young ones, with futures to think of, often feel that they can't afford to take low-paying jobs with limited opportunities for advancement. The midcareer people, in contrast, with their children grown, with their mortgages paid down, and with some retirement income coming in, can afford the luxury of being teachers.

"Individuals give varied reasons for wanting to become classroom teachers at midcareer," says Katherine K. Merseth, director of the Harvard Graduate School of Education's midcareer math and science program. "Many come seeking a change in the quality of their lives and an opportunity to contribute to the education of young people."

Merseth notes that the Harvard program began in fall 1983 with a class of seven students and expanded to 20 students in 1984. The number of participants is limited, she says, "because those in midcareer need specific support and assistance in making this transition." Although 20 is a small number in the face of the shortage, she adds, the program serves as a model for other schools. The University of Vermont and Washington University (St. Louis) already have similar programs and others are being planned.

For example, Purdue University has just revealed the details of its new program designed specifically to lead to certification for midcareer scientists who want to teach in Indiana secondary schools (C&EN, March 3, page 32). The first class is due to begin this fall.

Chemical educator J. Dudley Herron, director of the new program, notes that midcareer scientists have indicated "that they are unwilling to commit long periods of time to prepare to teach." So the Purdue program is designed to meet certification requirements in one academic year.

The program will emphasize practical experience in the classroom, Herron says. Participants will, among other things, observe classes in public schools, help teach introductory college science courses, and work on special projects. The last nine weeks of the program will be spent teaching science under the supervision of an experienced teacher.

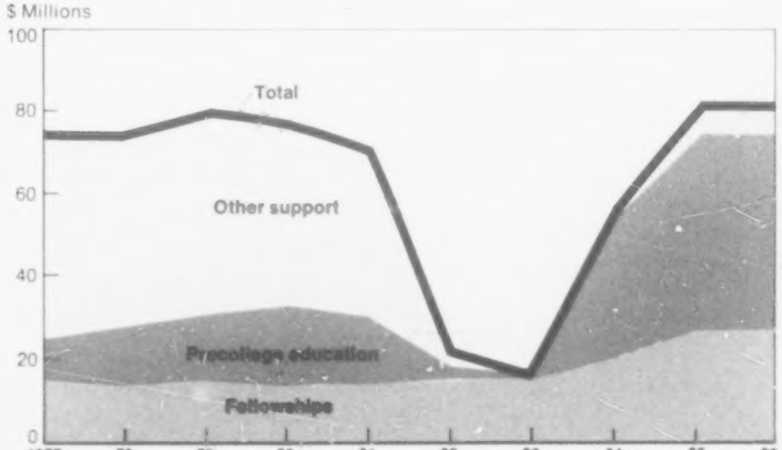
F. James Rutherford, chief education officer of the American Association for the Advancement of Science, comments that only marginal headway has been made so far. "Laws have been passed, curriculums changed, state requirements increased, but nothing much has really happened." One big reason, as usual, is lack of money. "Out of a billion federal dollars promised, only about $45 million has been realized," he says. Much of that, he adds, has gone just to maintain the status quo. Nor is Rutherford optimistic about the future. "People will always say they care about education, and they mean it. But it's something down the road. We haven't yet provided the incentives for real change. We have a long way to go."

Bassam Z. Shakhashiri, head of the National Science Foundation's Science & Engineering Education Directorate (SEED), concurs that there's still a long way to go. Yet, he argues, quite a bit has been accomplished. For one thing, the re-establishment of SEED in October 1983, after its abolition a year earlier, was in itself a large step in the right direction.

Shakhashiri, a University of Wisconsin chemistry professor, has long been well known in chemical education circles as an enthusiastic advocate of precollege science instruction. He was instrumental in establishing the Institute for Chemical Education, which so far has concentrated its efforts on programs for precollege teachers (C&EN, April 9, 1984, page 28).

Not surprisingly, Shakhashiri considers his appointment as "a mandate to focus on precollege programs." Of his total fiscal 1985 budget of $87 million, more than $50 million was earmarked for such programs, with roughly half going for development of new instructional materials and half for training programs for elementary and secondary school teachers. A similar amount is budgeted for fiscal 1986, but Shakhashiri expects a cut of 4.3%, effective March 1, as a result of the Gramm-Rudman-Hollings act. Current plans call for

More than half of NSF's education budget now goes to precollege programs



Note: Fiscal years. **Source:** National Science Foundation

Fowler (left): generous Carnegie Foundation grant
Shakhashiri: involve practitioners with educators

an $89 million total SEED budget for fiscal 1987, but that amount will almost surely be cut, perhaps 20 or 25%, again as a result of Gramm-Rudman.

When Shakhashiri came to SEED in June 1984, one of his first tasks was to reassemble a qualified staff. The staff now totals 65 and it is, Shakhashiri says, highly qualified. He notes that a high school teacher and an elementary school teacher are among his program officers, but denies that they are in any way tokens. "I hired them for their expertise," he says.

Moreover, the staff includes four people who were on the ACS task force on chemical education: chairman Yankwich, who now serves as SEED's senior executive officer; Jerry A. Bell of Simmons College, who heads the division of teacher preparation and enhancement; associate program director Ethel L. Schultz (a high school teacher from Marblehead, Mass.); and Shakhashiri himself.

Regarding current SEED activities, Shakhashiri says there's a special thrust to improve science and math education at the elementary and middle school levels, noting that these are the critical years in forming attitudes towards those subjects. And because NSF funds are limited, SEED must play a "catalytic role, investing in targeted areas."

In line with that policy, SEED this year has issued targeted program solicitations inviting proposals for grants for programs in three areas: preparing new middle school science and math teachers, developing new materials for elementary school science instruction, and developing new materials for elementary school mathematics instruction. Next year, Shakhashiri says, other high-priority areas will be targeted.

Shakhashiri adds that he would like to deliver one message: "It's very important to involve science practitioners with science educators," he says. In that respect, he adds, he's still a teacher. "But now my students are the NSF people and the people on Capitol Hill who need to know what kinds of programs deserve support."

The rebirth of NSF's education directorate is only one manifestation of renewed and continuing national interest in precollege education. Many other efforts are under way. Most of these efforts, understandably, are intended to furnish quick fixes for acute problems. Others, however, are looking much further ahead.

AAAS's Rutherford points out, for example, that there's no shortage of reports lamenting the shortcomings of science and math education in U.S. schools. However, he says, none of these reports have dealt well with the questions of exactly what students should be learning in those areas.

To provide some answers to those questions, AAAS has launched what it calls Project 2061. That name was chosen because 2061 is the year that Halley's comet will next return to Earth's part of the universe. The idea is to stress the long-term goals of the project. Initial support is being provided by the Carnegie Foundation.

Phase I of the three-phase project sets out to answer the question, "Out of all the possibilities, what science and technology is most worth learning by all young people by the time they leave high school?" Target date for completion is 1987. AAAS notes that the intent is to "provide a foundation that will serve all students" and that no distinctions will be made between college-bound and other students.

Phase II will involve the formulation of recommendations for curricula, teacher training, testing, and school organization, all based on the answers obtained in phase I. "Eventually," AAAS says, "phase III will spearhead the implementation of changes in the schools."

Contrary to the beliefs of those who live there, important things do happen outside of Washington, D.C. Perhaps one of the most significant and gratifying trends to emerge since the crisis has been the springing up of local and regional alliances between schools and businesses, aimed at improving public school education in general and science and math education in particular.

These alliances typically have names like Business/Education Together (California), Partners in Education (Illinois), or Center for the Advancement of Science Education (Wisconsin). It's hard to get an accurate count of just how many such ventures there are. One source document lists more than 50 alliances, but many of these are state or regional agencies that provide coordination and services to a number of local business-education partnerships. The actual number of such local partnerships is probably in the low hundreds.

In addition, an umbrella organization, the Triangle Coalition, has recently been established and is based in Washington, D.C. It describes itself as "a joint council of representatives from business, industry, labor, education, science, and engineering groups that have committed some of their resources to the improvement of science teaching."

Reflecting its joint nature, the coalition has three chairmen: one from education (Mary Futrell, president of the National Education Association), one from industry (Du Pont executive vice president Robert C. Forney), and one from science (University of California, Berkeley, chemistry professor Glenn T. Seaborg). A steering committee of prominent persons from various companies and organizations provides policy guidance. John M. Fowler, special projects officer for the National Science Teachers Association, acts as staff director.

The Triangle Coalition is funded by assessments on its member organizations (there are currently about 40 members; ACS is one of them) and by grants from other sources. Fowler notes, for example, that a "generous" two-year, $250,000 grant by the Carnegie Foundation has just been approved.

Several projects are under way or planned. For example, a clearinghouse of information on local alliances has been set up and a newsletter to share information and ideas among alliances has begun. Another project will promote the formation of new alliances. Still another involves establishing an inventory and database of programs that offer direct assistance to teachers.

Also in the works is a brochure to promote the idea of "minigrant" programs for schools and teachers and to provide guidelines for establishing and operating such programs. In addition, the coalition is cooperating with NSF in promoting National Science Week. It also is making plans for a national conference on elementary science and technology education, to be held later this year.

Chemical companies and other science and technology-oriented firms have been playing an increasingly important role in furthering the cause, both within business-education partnerships and in independent efforts.

For example, Dow Chemical chairman Robert W. Lundeen also is chairman of Michigan's Partnerships for Education Task Force. Projects Dow has participated in or contributed to include a technology workshop for Detroit public school students and the development of two chemistry shows for presentation at school assemblies. Dow also is encouraging each of its 25 locations to establish award programs for teachers in their communities and provides some funds for that purpose.

In Philadelphia, Theodore A. Burtis, chairman of Sun Co., chairs another local alliance, PRISM (for Philadelphia Renaissance in Science and Mathematics). Current PRISM activities include a science materials center, a science/math clearinghouse, a "teachers in industry program," a minigrants program to support innovative science/math projects, an "urban math collaborative" for secondary math teachers, and a program to attract minority students to engineering careers.

Du Pont notes that it has joined with school districts that serve a number of its major facilities in a program to help send community science teachers to regional and national NSTA meetings. For example, the company has provided grants to cover registration, transportation, and lodging for the teachers chosen by their districts. It also has made $3000 grants to each school district "to implement teacher initiatives arising from their NSTA experiences."

Amoco has made sizable grants to support two new precollege programs. One will provide training for science and math teachers in Chicago's public schools. Another, to the University of Chicago School Mathematics Project, will help underwrite the development of a new, applications-oriented math curriculum for K-12 students.

The American Chemical Society, which has had an office of high school chemistry since 1979, now has authorized a staff position for prehigh school science, according to Sylvia A. Ware, acting manager of precollege programs for ACS. However, that position hasn't yet been filled.

"Chemistry in the Community" (ChemCom), an ACS-developed interdisciplinary science course for 10th graders has progressed to the point that it is now undergoing field testing with more than 3000 students in 13 states. W. Thomas Lippincott, director of the project, notes that both students and teachers seem pleased with the ChemCom approach. Plans for commercial publication are going on, as are plans to revise the materials (following the field tests) and plans to help acquaint chemistry teachers around the country with the structure and nature of ChemCom.

The few examples described in this article are by no means a complete list. Across the country, there are many, many other initiatives under way, involving all levels of government as well as educational institutions, scientific and professional organizations, and private companies. Taken together, they afford considerable comfort—suggesting that even in the absence of a crisis atmosphere, some progress has been made in curing the ills of precollege science and math education. ☐

Chemical productivity rose nearly 6% in 1985

Productivity in the chemical industry rose in 1985. Not so surprising, considering the massive layoffs and early retirement programs in the chemical industry in the past year. The increase, however, trailed that for all manufacturing (including the chemical sector). Still, it was ahead of the rise for chemicals in 1984.

Using production data from the Federal Reserve Board and hours of production from the Labor Department, C&EN calculates that productivity (output per production workhour) for chemicals and allied products last year rose 5.9% to an index of 135.6 (1977 = 100). This follows a 4.0% rise in 1984, and an 11% increase in the postrecession year of 1983.

The index for all manufacturing climbed 9.2% to 135.4 from the year before when it rose only 1.5%. In 1983, it increased 6.9%.

Using hourly production wages from the Labor Department, C&EN calculates that unit labor costs (production wages per unit of output) for chemicals and allied products in 1985 fell 1.5% to an index of 132.9. In 1984, this index was up 0.7% following a 4.2% decline in 1983. For all manufacturing, the 1985 index was 123.2, down 3% from 1984, which was up 2.3% from the year before. In 1983, unit labor costs declined 2.7% for all manufacturing.

Although the full year showed moderately good results for the chemical industry, fourth-quarter 1985 productivity figures were mixed. The data show the fourth-quarter chemicals and allied products index amounted to 137.6, an increase of 6.7% from the year before, but up only 0.3% from the third quarter. In the third quarter, the index showed an annual increase of 6.0% and a quarter-to-quarter rise of 2.0%.

For all manufacturing, the index in the fourth quarter was 136.0, up 8.7% from the same period the year before, but down 0.6% from the previous quarter. In the third quarter, the index rose 8.8% for the year and 1.0% for the quarter.

Unit labor costs for chemicals in the fourth quarter fell 2.4% on an annual basis to an index of 133.7, but rose 1.4% from the third quarter. In the third quarter, they were down 1.6% from a year earlier and 0.7% on a quarter-to-quarter basis. For all manufacturing, the index in the fourth quarter amounted to 124.5, a drop of 4.9% from the year-earlier period, but up 1.7% from the third quarter. This follows an annual decline of 4.7% in the third quarter and a quarterly decrease of 0.7% in that period.

William Storck, New York

Productivity was level in fourth quarter as unit labor costs rose . . .

	Quarters, 1985				Quarters, 1984				Quarters, 1983			
Indexes, 1977 = 100	4th	3rd	2nd	1st	4th	3rd	2nd	1st	4th	3rd	2nd	1st
CHEMICALS AND ALLIED PRODUCTS												
Production	128.1	127.9	126.3	126.0	123.2	124.6	123.4	120.5	121.2	119.0	113.8	108.7
Workhours	93.1	93.2	93.9	94.7	95.6	96.3	96.0	96.2	95.1	94.2	93.7	92.6
Productivity[a]	137.6	137.2	134.5	133.1	128.9	129.4	128.5	125.3	124.7	126.3	121.5	117.3
Hourly production wages	183.9	180.9	178.6	177.3	176.5	173.5	171.2	169.8	168.7	165.4	163.3	161.5
Unit labor costs[b]	133.7	131.8	132.8	133.2	136.9	134.0	133.2	135.5	132.5	131.0	134.5	137.7
ALL MANUFACTURING												
Production	128.3	127.6	126.5	126.0	120.3	120.8	118.8	116.3	121.2	119.0	113.8	108.7
Workhours	94.3	93.2	93.4	94.5	96.1	96.0	96.3	95.4	92.9	86.5	87.1	84.3
Productivity[a]	136.0	136.9	135.5	133.3	125.1	125.8	123.3	121.9	121.7	128.0	120.4	118.7
Hourly production wages	169.4	167.6	167.0	163.6	163.8	161.6	160.6	159.8	157.9	155.6	154.4	153.5
Unit labor costs[b]	124.5	122.5	123.3	122.7	131.0	128.5	130.2	131.1	129.7	121.9	128.2	129.4

. . . but for the year, productivity increased and costs fell

	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
CHEMICALS & ALLIED PRODUCTS											
Production	127.1	122.9	115.7	105.6	116.0	110.0	113.3	106.3	100.0	92.0	79.3
Workhours	93.7	96.0	93.9	95.2	101.7	101.0	103.1	102.2	100.0	97.3	92.6
Productivity[a]	135.6	128.0	123.1	110.9	114.1	110.0	109.9	104.0	100.0	94.6	85.6
Hourly production wages	180.2	172.7	164.8	155.0	141.8	129.2	[illegible]	109.2	100.0	91.9	83.8
Unit labor costs[b]	132.9	134.9	133.9	139.7	124.4	117.5	[illegible]	105.0	100.0	97.2	97.9
ALL MANUFACTURING											
Production	127.1	119.1	115.7	99.4	108.6	105.9	110.7	106.1	100.0	94.1	84.0
Workhours	93.9	96.0	87.7	97.0	97.9	98.9	106.2	104.5	100.0	96.1	90.4
Productivity[a]	135.4	124.0	122.2	114.3	110.9	107.1	104.2	101.5	100.0	97.9	92.9
Hourly production wages	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6	100.0	91.9	85.0
Unit labor costs[b]	123.2	130.2	127.3	130.9	126.8	116.6	113.2	107.0	100.0	93.8	91.5

a Productivity is output per workhour, calculated by dividing indexes for production by indexes of workhours of production employees. **b** Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes of output per workhour. **Sources**: Department of Labor, Federal Reserve Board, C&EN estimates

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MARCH 17, 1986

NEWS

U.K. Research Funding

Universities grapple with tighter budgets
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NEWS

MARCH 17, 1986

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- **Ronald Wigington will succeed Dale Baker as director of Chemical Abstracts Service.** **Page 5**
- **CMA says a broad-based tax to finance Superfund would be more equitable.** **Page 5**
- **National Research Council report indicates cause-and-effect relationships between sulfur dioxide emissions and acidification of bodies of water.** **Page 6**
- **Supreme Court rules illegal New Jersey law taxing firms to pay for cleanup of abandoned chemical waste sites.** **Page 6**

Cover: Photo by C&EN's Dermot A. O'Sullivan

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Business

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Communist Party Congress seeks to realize the U.S.S.R.'s economic potential through high-tech approach. **Page 19**

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Oxygen-containing molecule with 11 iron atoms, made by research team at MIT, may give clues to how ferritin is built up. **Page 22**

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Establishment of lobbying group called Save British Science points up concern of U.K. scientists over declining level of government support for research. **Page 7**

U.K. Scientists Fret over Slide in Funding for University Research

Declining level of government support for research has provoked concern over the impact on British science and scientists' morale, triggered formation of lobbying group called Save British Science

Dermot A. O'Sullivan, C&EN London

In a January issue of the *London Times* readers were confronted with an impressive looking half-page advertisement with the banner headline, "Save British Science."

The ad read in part, "British science is in crisis. Opportunities are missed, scientists emigrate, whole areas of research are in jeopardy. Government's support for research is declining, falling behind that of our main industrial competitors in Europe. There is no excuse. We can and must afford basic research, Britain's investment for the future."

Run by the Save British Science (SBS) group, the ad was generated by concern on the part of U.K. scientists about the declining level of governmental financial support. "We face the government's predominant policy to curtail public spending. And since science funding is part of public spending, it, too, is being kept down," explains John Mulvey, a particle physicist at Oxford University, and one of the founders of the group.

The reason for the scientists' discontent is what they see as the declining pattern of the government's spending on civil research over the past decade or so in relation to the country's gross domestic product (GDP), or total wealth, and the likelihood that this pattern will continue. For instance, during 1984–85 (the government's accounting year runs from April through March), the science budget of the Advisory Board for the Research Councils totaled $691 million—based on $1.00 = £0.796, the average value for the period April 1984 through March 1985. (This value is used throughout for direct year-to-year comparisons.) That was a mere 0.17% of the country's GDP, essentially unchanged during the previous 10 years.

In absolute "money of the day" terms, the 1984–85 budget was 350% more than it was 10 years earlier, and represented a 13.3% yearly rise. When the figures are corrected for inflation, on the other hand, the overall increase is less than 8%, and the per-year growth averages 0.76%.

How these figures relate to the spending on civil research in other countries must be treated with some caution. For one thing, definitions of expenditure or the source of funding don't precisely match from one to another. However, the London-based Committee of Vice-Chancellors & Principals (CVCP) of universities makes the point, "Civil R&D, both inside and outside the universities, has been running at only 1.6% of the GDP in Britain. This compares with 2% in the U.S., and 2.5% in West Germany and Japan."

Save British Science developed out of discussions Mulvey had with several colleagues last fall. "It stemmed from realization that the problem is broader than our own individual ones," he recalls. "It became clear that there was need for scientists in all disciplines to come together and present their point if there is to be any improvement in the situation. Until now, there has been no coherent case put to government for the support of civilian science."

Rise in U.K.'s science R&D support budget outpaced by astronomy, engineering

$ Millions	1984–85[a]	Per cent	1983–84[a]	Per cent	% change
Astronomy, space & radio	$ 59.33	17%	$ 51.10	16%	16%
Engineering	90.74	26	76.65	24	18
Nuclear physics	76.78	22	70.26	22	9
Science	94.23	27	86.23	27	9
Centrally supported activities	13.96	4	22.36	7	−38
Administration	13.96	4	12.77	4	9
TOTAL	$349.00	100%	$319.37	100%	9%

a Fiscal year April 1 through March 31. Note: Conversion rate of $1.00 = £0.796, the average value for the period April 1984 through March 1985 used for both years. Source: U.K. Science & Engineering Research Council

C&EN staff photos

Mulvey: need to do more to overcome antiscience feeling

Encouraged by the response to a spot check of other scientists throughout the country, a committee was set up with Joseph Lamb, professor of physiology at St. Andrew's University in Scotland, as chairman, and Jeremy Leggett of the geology department at London's Imperial College of Science & Technology as treasurer. Others who have since joined the committee span the sciences from anatomy, animal behavior, and astronomy, to psychology and theoretical physics.

Members of Parliament interested in the state of scientific research in the U.K. have applauded the initiative. And CVCP says, "We welcome the campaign launched by many distinguished scientists to draw public attention to the crisis in the funding of scientific research."

Since its launching in December, the number associated with SBS has swelled to about 1800, eight of them Nobel Laureates. Voluntary contributions now total about $23,000. Some of the money has come from the general public.

Fender: trying to put political pressure on government

There is no set dues structure, but the fact that each individual has made a donation out of his or her pocket, according to Mulvey, is an indication of the depth of feeling on the issue, and the desire to see something done about it. "Scientists, especially the younger ones, are saying, 'We now have a channel for demonstrating our concern.' That has been an encouraging outcome of the campaign so far," he notes.

He readily acknowledges that SBS is a lobbying group, which, he points out, is unusual for British scientists to be involved in. "They wouldn't be driven to this atypical, and some might consider undignified, action unless there were a serious driving need," he adds.

"Much of the trouble that science in the U.K. is in right now stems from the fact that we as scientists have paid too little attention to the very serious and very difficult problem of communicating to the population generally just what science entails," he believes. "There is much antiscience feeling about, and we haven't done enough to overcome it. Nor have we taken the trouble of talking to our members of Parliament on the subject."

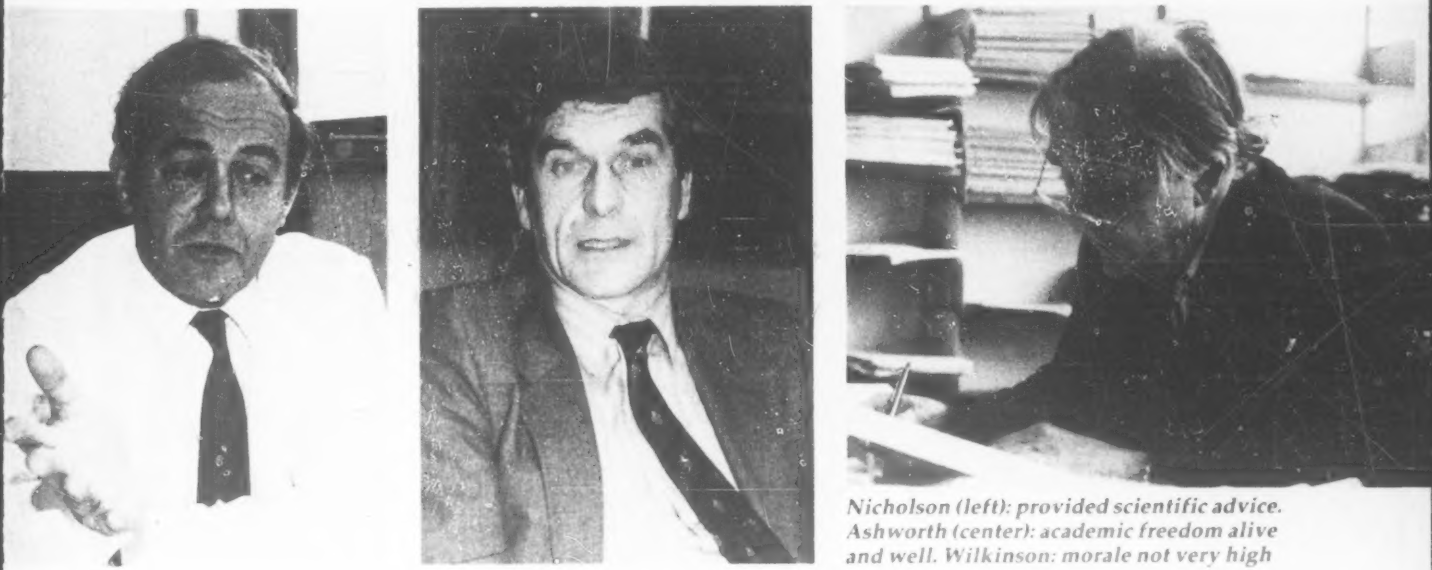
"It's true that most other countries appear to see the need to put a real increase into their science budgets," says Brian Fender, vice chancellor of Keel University, a former nuclear physicist, and chairman of the Science & Research Engineering Council. "That is not evident in this country. The problem in Britain is that as well as the contraction in funding by the government's University Grants Committee (UGC), there is no more than level funding from the research councils' side.

"I suppose the government is entitled to say that we must demonstrate our case more strongly. And to some extent Save British Science, quite rightly, is trying to achieve political pressure on the government to alter its policy."

For British scientists—chemists in particular—the situation is the more frustrating considering that Prime Minister Margaret Thatcher has a B.S. degree in chemistry, worked in the industry, and at one time headed the government's department of education and science. When the Conservative Party she heads was returned to power in 1979, the general assumption was that she would have a more understanding attitude of the needs of science.

Sir Robin Nicholson, chief executive of Pilkington's electro-optical division, sympathizes with this view of Thatcher. But he insists that Thatcher demands background briefing on the scientific implications of the many and varied issues that she and her Cabinet must decide on "to a degree greater than any of her predecessors."

He speaks from firsthand experience. Before he joined Pilkington in January, he was the British government's top scientist, serving four years as chief scientific adviser in the Cabinet office, which in Britain, he notes, is a nonpolitical appointment.



Nicholson (left): provided scientific advice. Ashworth (center): academic freedom alive and well. Wilkinson: morale not very high

"I was continually called on to provide her detailed scientific advice on a wide range of topics," he recalls. Although she is not oblivious to the importance of science and its needs, Thatcher and her Conservative Party were voted twice into power on a manifesto to cut public spending and bring down inflation, which she has done, Nicholson points out.

Nonmilitary scientific research in the U.K. is funded almost completely by the government through what is known as the dual support system. One arm of this is UGC. The other comprises the research councils of which there are five: Agricultural & Food Research Council (AFRC), Economic & Social Research Council (ESRC), Medical Research Council (MRC), Natural Environment Research Council (NERC), and Science & Engineering Research Council (SERC). SERC provides the bulk of the funding for the core sciences—biology, chemistry, physics, and the like—although some money for research in these areas comes also from AFRC, MRC, and NERC.

Money from UGC goes toward the upkeep and running of the 50 or so universities and 30 polytechnic colleges throughout the U.K. Part of it is channeled to the science departments. The actual amount isn't easy to assess accurately because each institution makes its own decision on how to apportion its funds. However, as a general rule, it is more or less in line with that coming through the research councils. For example, during 1984–85, the UGC outlay totaled $1.59 billion. From this, an estimated $711 million (45%) went to provide the basis for research capability in the science departments.

In its December statement, "The Future of the Universities," CVCP emphasizes, "The UGC element of the dual system, the general recurrent and equipment grant, has declined since the mid-1970s, dramatically so in the 1980s. UGC itself has pointed out that the value of the equipment grant fell over 30% in the 1970s, and has continued to fall since, and that some [$477 million] would be required to restore its value." Nevertheless, in a further drive to economize, UGC funding in the coming three years is geared to grow at a rate 2% less than the prevailing rate of inflation.

By comparison, the research councils' spending totaled $664 million. SERC made up the largest share ($349 million), followed by MRC ($147 million), NERC ($82 million), AFRC ($58 million), and ESRC ($28 million).

Some universities have taken positive steps to overcome the severe cuts in their budgets of a few years back. An example is what has happened at Salford University, near Manchester, which saw its recurrent grant sliced 44% in 1981. There, a commercial offshoot has been formed, Salford University Industrial Center. Wholly owned by the university, SUIC was revitalized by John M. Ashworth, a former biochemist who became vice chancellor when he stepped down as chief scientific adviser in the Cabinet office the same year.

Some consulting work already was being undertaken at Salford at the time, but sales were only $600,000 or so a year, he recalls, "too small to be useful, but big enough to be distracting. So I decided that we must either shut it down or make it bigger. I brought in professional management, gave the center the objective of maximizing profits, and geared it into a growth mode."

SUIC now has a staff of about 50 (they are not on the university's payroll), and income has increased 10-fold. "Many of the contracts are short term and don't involve academics," he notes, "but for major undertakings there are mixed teams of SUIC employees and academics, mostly from the science and engineering departments." SUIC, and the new satellite companies going in, has access to the university's specialized equipment and services.

"I am trying to show that it is perfectly legitimate for a university academic to be interested in things downstream from the traditional research as it is known in British universities," Ashworth says. "There is a further positive benefit. Involvement in such activities is reflected back into the teaching of undergraduates. Chemists that come out of our university have their feet on the ground."

No less important, of course, is that SUIC is an important source of revenue for the university. Last year it provided some $400,000, which was reinvested. "Indeed, we are dependent on SUIC," Ashworth admits. "If the projects weren't profitable, the university's finances would have a real hole in them."

Ironically, he now is worried that the university funding will rise higher than the current 40% coming from industry. "My problem is to stop it there. Nobody knows what an institution would be like that gets most of its money from noneducational means. I would then be akin to being managing director of the University of Salford Inc., a subsidiary of which happens to be in education and training. We should not stumble into that situation without thought."

Ashworth insists that he remains an academic at heart. "It's quite proper for people who wish to do so to continue doing fundamental research. Academic freedom is alive and well at the University of Salford. But the research has to be the best. There is no point in doing second-rate fundamental research." For such people, he reasons, being engaged in research that is more at the applied end of science and engineering "is every bit as important," he adds.

In light of the government funding cutbacks, it's not surprising that chemistry departments aren't the happiest of places to be working these days in the U.K. The funding squeeze is affecting their running and the level of research conducted there.

"Morale is not very high," admits Sir Geoffrey Wilkinson, who heads the chemistry department at London's prestigious Imperial College of Science & Technology. An inorganic chemist of international renown and winner of the 1973 Nobel Prize in Chemistry (which he shared with West Germany's Ernst O. Fischer) for work on organometallic sandwich compounds, he is concerned about the low number of junior positions available for postdoctoral research.

"If more such positions were available, it would give young aspiring research chemists who wished to pursue a university career something to look forward to," he says. "But there is no wild enthusiasm for academic life because prospects don't look bright."

Despite a downward shift in the number of undergraduate chemistry students, there is no evidence as yet of a dropoff in the numbers going on for a Ph.D. Indeed, this year at Imperial College, 138 students are working toward their doctorate—the largest number ever, Wilkinson notes. Those with Ph.D.s for the most part leave to take jobs in industry.

"A new Ph.D. here usually starts work in industry at a salary of about $15,000," he points out. That's more attractive than the $10,000 or so the person could expect from an academic postdoctoral post, he admits. "So anybody who gets a Ph.D. and is offered a job in industry is well advised to take it," he says.

"My research budget has been going up about 2% a year. Taking inflation into account, I have been falling behind. And this is on top of a direct cut of 30% in the departmental budget about three years ago. All postdoctoral positions had to be sacrificed."

Wilkinson also cites the $817 or so annually that SERC provides for each research training support grant as being inadequate. "It costs us about $2500 a year to keep a person at the bench for synthesis work. So every new person who works here on such a grant is a further drain on our budget. One way we are trying to cope is by replacing expensive experiments at the undergraduate level with cheaper ones."

His 1985 chemistry department budget was $1.6 million. About 82% of that went for salaries. From the remainder, the running of teaching labs and of the departmental instruments, as well as the cost of general administrative services, the library, and workshops had to be funded. That left $94,000 or so split among inorganic, organic, and physical chemistry to pay for materials needed in research.

Seeking funding for purchasing new equipment has its own set of problems. For the more sophisticated items, SERC requires a contribution of about 30% from the university's budget.

"It's clear to all that some areas of science, chemistry among them, are being whittled away in the U.K.," Wilkinson maintains. "Support for chemistry comes to about 8% of the total SERC annual budget despite the importance of chemistry to the U.K. economy."

The comments of Jack E. Baldwin, professor of organic chemistry at Oxford University and an authority on the structure and synthesis of penicillins, mirror those of Sir Geoffrey. "What is happening is that the morale here in the U.K. is so bad that it is damaging," Baldwin says. "We don't have adequate equipment levels, we can't get money easily to do our research. The whole thing is sliding downhill."

"The way it's going now, I think it's destroying the science of chemistry in this country," he says bluntly. "Unless SERC and the government abruptly change their policy, we will be in a position where not only do we have a second-rate university system, but worse and much more important we will have a second-rate industrial chemical system. And the chemical industry in this country is about the best industry we've got. It's making money. If they throw that out the window, what will we have after the year 2000? It's very, very foolish."

Baldwin acknowledges that there is some financial support for university chemistry departments through the Cooperative Awards for Science & Engineering (CASE) scheme set up a few years ago to increase interaction between universities and industry. "There's a good argument for part of it. But the projects tend to be biased along company lines. In some respects it has worked against us, because companies can claim they are supporting universities through CASE rather than by direct grants."

Baldwin gets some funding for his research from pharmaceutical companies. But he insists on freedom to publish his results after a delay of three months when the company has had an opportunity of evaluating them.

Not one to mince words, Baldwin has some radical views on the U.K.'s system of higher education. "One of the problems in this country is that we've got too many departments of chemistry. There are more than 80 establishments that give Ph.D. degrees in chemistry. There is no way that we can support more than 25 engaged in first-rate research. We should invest our resources where we can get the most return for them. And that isn't by spreading them in a thin layer throughout the U.K."

Speaking from his experience of working in the U.S., where he was on the chemistry faculty at Pennsylvania State University for three years followed by eight years as chemistry professor at MIT, he also believes that U.K. university staff members should be paid in accordance with their achievements. "Here, all salaries are fixed. There's no flexibility. You can't encourage good people by giving them raises, or discourage weaker ones by reducing their pay.

"The most important change that could occur in British universities is to have very substantial differential salaries, as is the case in the U.S.," he maintains. "Geoffrey Wilkinson won a Nobel Prize, but he doesn't get any more money. He got a knighthood."

He decries the fact that so much of the funding coming from SERC goes toward costly experiments in astronomy, nuclear physics, and the like, noting the mere $9 million that goes directly to university chemistry departments out of the total expenditure of $349 million during 1984-85. "No high-energy physics experiment has any commercial possibility, whereas it's quite likely that some chemists will make very important discoveries that will have all sorts of commercial potential."

In a rebuttal to this line of thinking, SBS's John Mulvey points out, "This is an argument that's a lot older than the past three years. If you look back over the history of science, you will always find incidents of one branch of science attacking another. But it's a very dangerous path to enter. We should recognize the unity of science. A lot of what chemists are doing today wouldn't be possible if physicists hadn't been 'wasting their time' doing their research 20 or so years ago."

Sir David Phillips, professor of molecular biophysics at Oxford, who serves as chairman of the Advisory Board for the Research Councils (ABRC), also points to the fact that expensive equipment such as that at the Rutherford Appleton Laboratory near Oxford, with its new spallation neutron source, is for use by scientists generally. Among them, chemists form a large proportion, he says.

He concurs that "chemistry, like everything else, has become much more capital intensive than it used to be. One can't do frontier-type research without such tools as NMR and mass spectroscopy. But to suppose that these tools can be distributed throughout all the labs in the country that are doing chemistry seems to me to be a nonstarter."

Phillips and his ABRC colleagues have the difficult task of apportioning the funds coming through the department of education and science. Of the $691 million spent in 1984–85, 50.5% ($349 million) went to SERC, 21.3% ($147 million) to MRC, 11.9% ($82 million) to NERC, 8.4% ($58 million) to AFRC, and 4% ($28 million) to ESRC. Some of the $27 million balance went to the British Museum of Natural History and the Royal Society.

Faced with the prospect of cash shortages for research funding in the immediate future, ABRC got welcome relief late last year when the government decided to inject an additional $19 million annually into ABRC's budget during the coming three years. In 1986–87, the cash grant now will be $771 million, 5% over the current year. For the two years following, there will be a rise of some 2.5% a year to $789 million in 1987 and $809 million in 1988.

Baldwin (above): sliding down hill. Phillips (center): will lose ground. Reece: viability of universities is key

"Although it is less than we recommended was needed, it will make a valuable contribution to sustaining the science base," Phillips told Sir Keith Joseph, Minister of Education & Science. But as one scientist points out somewhat cynically, "The government made a big present of the $44 million. But it won't correct for inflation over the time span. So funding still is set to go down in real terms. If there is a science policy, it is a policy of decline. One can't plan ahead under those circumstances. One doesn't know what is ahead."

Phillips observes that U.K. industry's contribution to the country's civil R&D funding is about 40% of the total. "If government's contribution were held constant and industry's increased to 60% of the total rather than 40%, I believe we would compare quite well with what other countries are spending.

"What worries me is that industry won't change its attitude all that quickly. And if government insists that it is doing all it can, then we will continue at a disadvantage and lose ground over an interim period of undefined length. That would be very dangerous in my view. Somehow I hope that government will fill the gap while industry's attitude is evolving."

Charles H. Reece, Imperial Chemical Industries' director of research and technology, acknowledges that "morale of the scientific community at U.K. universities has been badly dented. The reason," he explains, "is that everything is being done in such a short time frame. Universities used to function on a five-year rolling basis. Now they don't know where they are from one year to the next."

For ICI, the continuing viability of Britain's universities is of key significance. "About 70% of our science is done here," he notes. "Although that might change a little, it won't change by much. The U.K. will be our main kernel of scientific knowledge for quite a number of years, if not forever. So it is important that we have a healthy university scientific community.

"What industry wants from universities is not inventions. We can invent better than they can. We look to U.K. universities to provide well-trained scientists of sufficient excellence to be on equal terms with other international bodies of researchers, and familiar with all the modern techniques to bring to bear on a problem."

He cites a number of ways that his company contributes to ensure that this is so. ICI gives nearly $4 million or so a year to U.K. universities in one form or another. For example, upward of 300 Ph.D. students work part time at ICI labs, part time at universities, and some 70 of its staff members teach at the professorial level. Also, a number of ICI people play an active part on various SERC committees.

The company spends about $628,000 annually on selective lines of research at 25 universities in the U.K., two in Belgium, one in France, and at Massachusetts Institute of Technology and the University of Texas. "I would like the figure to go to about $942,000," Reece says. "We have more projects to consider than we have funds to cover them. All this is done at the postdoc level."

About 10 projects chosen annually continue for a three-year term. Areas of study are diverse, and not necessarily of immediate potential commercial interest to ICI. They range from x-ray crystallography of proteins to polypeptides, biomaterials, molecular biology, and solid-state physics.

Of course, ICI isn't alone among U.K. companies promoting scientific research at the universities. A number are involved to varying degrees. For instance, British Petroleum set up what it calls its Blue Skies program six years ago. Working with a budget of some $2 million a year, Don Braben, who heads the program at BP's London headquarters, currently supports 22 projects, many of them esoteric, at academic institutions mostly in the U.K. "We look for research of the type that may lead to innovation, and back individuals or small groups who need freedom to develop their ideas fully," he says.

Observes John I. Cadogan, BP's research director, past president of the Royal Society of Chemistry, and until recently chairman of SERC's science board, "The $9 million or so a year that SERC spends on research grants each in physics and chemistry simply is too small. More needs to be earmarked in the core sciences. Our ambitions in BP are to strengthen contacts between universities and industry."

Despite the spirit of gloom and doom among U.K. scientists, Keel University's Brian Fender, who succeeded Cadogan on the science board this year, sees a good side to the current situation. "There is a great deal more collaborative research going on now," he says. "Scientists recognize the virtues of getting together to tackle problems collaboratively. Very often this is interdisciplinary. Biologists and chemists may pull in the physicists to work alongside them. Another good feature is the increasing tendency to build into research projects involvement from industry."

He is very optimistic about the outcome of what he calls the theme approach he and his science board are pushing. Many of these themes have subthemes, and some of them can become research initiatives, he observes. Within the neurobiology and cognitive science theme, for instance, are the subthemes of neurochemistry, signaling and transmission, sensory and motor systems, cognition and artificial intelligence, and the like.

Research initiatives already are under way in such areas as low-dimensional structures, sensors and protein engineering, image interpretation, and invertebrate neuroscience. Being considered are catalysis and interfaces, molecular recognition and biological specificity, molecular electronics, inorganic nutrients, drugs and poisons, and molecular biology of membrane processes.

"One of the things we are trying to do at SERC is build bridges between disciplines," Fender adds. "It is an interesting fact that of the engineering funding by SERC, 17% goes to science departments. Just as one seeks to break down, where it's appropriate, the boundaries between physics and chemistry, or chemistry and biology, one should want to do it also between science and engineering." ☐

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NEWS

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INSTRUMENTATION '8

Software, hardware trends from the Pittsburgh Conference Page 21

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CHEMICAL & ENGINEERING NEWS

MARCH 24, 1986

News of the Week

- **Chemical industry capital spending fell 4.7% in 1985 from 1984 to $10.7 billion and prospects for an upswing are dim.** Page 4
- **President Reagan endorses U.S.-Canadian report affirming acid rain is a man-made problem.** Page 5
- **UN secretary-general accuses Iraq of using chemical weapons against Iranian troops.** Page 5
- **Small and medium-sized farms will fade out of existence unless the government can provide farmers with needed technology.** Page 5
- **Chemical Waste Management sues two federal agencies for causing delays in research burn of chemical wastes at sea.** Page 6

Cover: Photo by C&EN's James Krieger

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Business

Biotechnology industry shows overall gains in fourth quarter, but on an individual basis, company earnings are mixed. **Page 8**

Work-force reductions in the chemical industry cause varied personal results, depending on career goals of those affected. **Page 9**

Government

Fourteen-year impasse over pesticide law broken by new agreement between two groups; Congress starts hearings. **Page 14**

Science

Future of genetically altered bacteria field tests may be complicated by recent blunders made by Advanced Genetic Sciences. **Page 17**

Books

"Outrageous Misconduct: The Asbestos Industry on Trial" by Paul Brodeur contains harsh judgment and startling facts. **Page 75**

Instrumentation '86

The Pittsburgh Conference, a showcase for developments in analytical chemistry, evidenced the increase in lab automation and effects of biotechnology on instrumentation. Page 21

Biotech Earnings Mixed in Fourth Quarter

On an overall basis the fourth quarter of 1985 was a heady one for the biotechnology industry. The initial acquisition agreements for Hybritech (by Eli Lilly) and for Genetic Systems (by Bristol-Myers) put high values on the individual firms' technology. The Food & Drug Administration approved Genentech's genetically engineered human growth hormone, making it the first such product to be developed and brought to market independently by a biotechnology firm. Clinical trial results for interleukin-2 supplied by Cetus were very encouraging.

Still, on an individual basis, fourth-quarter financial results were mixed. At the same time that seven of a group of 15 representative firms were notching double-digit or better increases in revenues compared with fourth-quarter 1984, four firms were registering double-digit revenue declines.

Genentech, South San Francisco, Calif., continued to star. The company's revenues for the quarter jumped 43% to $25.9 million and brought revenues for the full year to $89.6 million. Sales of Protropin growth hormone, which was not introduced until late October, totaled $5.2 million, auguring well for this year. In fact, Linda I. Miller, biotechnology analyst for Paine Webber, estimates that 1986 Protropin sales will reach $35 million and notes that no competing products are expected during the next two years. In addition, Genentech is already receiving royalties on growth hormone being sold by KabiVitrum in a dozen European countries.

Monoclonal Antibodies, Mountain View, Calif., recorded its second consecutive quarterly profit in last year's fourth quarter. Operating revenues rose 84% from the year-earlier quarter. Product sales jumped 116% on the same basis and accounted for 86% of total operating revenues.

For Biogen, Cambridge, Mass., and Geneva, on the other hand, revenues plunged 55% in the fourth quarter and losses widened to $6.5 million from $2.2 million in the year-earlier period. For the year, revenues fell 32% and losses rose to $19.1 million from $13.1 million in 1984. The chief reason for the decline in revenues is a strategic decision to postpone licensing programs for gamma interferon and some other products until positive preliminary and clinical trial results are confirmed. According to chairman James L. Vincent, that would allow Biogen "to strike appropriate arrangements with strong partners that reflect the increase in the value" of the products.

Amgen, Thousand Oaks, Calif., posted a small profit for the second consecutive quarter on a 140% leap in revenues, chiefly because of a 226% increase in research and development fees. Higher contract revenue also helped bring total revenues at California Biotechnology, Mountain View, Calif., up 26% to $2.8 million in fourth-quarter 1985. Similarly, at DNA Plant Technology, Cinnaminson, N.J., an 84% jump in R&D fees lifted total revenues 19% in the quarter.

David Webber, New York

Several biotechnology firms had high earnings growth in fourth quarter

	FOURTH-QUARTER 1985[a]						FULL-YEAR 1985[a]					
	Revenues[b]	Earnings[c]	Change from 1984		Profit margin[d]		Revenues[b]	Earnings[c]	Change from 1984		Profit margin[d]	
	($ millions)		Revenues	Earnings	1985	1984	($ millions)		Revenues	Earnings	1985	1984
Amgen	$ 5.630	$ 0.085	140%	def	1.5%	def	$19.840	$ −1.375	132%	def	def	def
Applied Biosystems	12.388	2.524	48	49%	20.4	20.2%	36.807	7.156	57	82%	19.4%	16.8%
Biogen	4.198	−6.473	−55	def	def	def	21.449	−19.062	−32	def	def	def
California Biotechnology	2.750	−0.236	26	def	def	def	9.583	−0.454	16	def	def	def
Centocor	6.930	0.840	69	318	12.1	4.9	22.355	1.999	74	401	8.9	3.1
Cetus	13.448	0.613	2	505	4.6	0.8	45.897	1.466	−23	53	3.2	1.6
Collaborative Research	2.315	−0.926	9	def	def	def	6.657	−3.179	−15	def	def	def
Damon Biotech	0.735	−2.281	−34	def	def	def	3.304	−10.645	−35	def	def	def
DNA Plant Technology	1.228	−0.034	19	def	def	1.4	4.484	−0.441	30	def	def	def
Genentech	25.870	2.183	43	257	8.4	3.4	89.599	5.608	28	106	6.3	3.9
Genex	2.000	−1.800	−78	def	def	def	16.200	−8.600	−39	def	def	def
Immunex	0.874	−1.093	−39	def	def	def	3.226	−4.422	−7	def	def	def
Molecular Genetics	2.157	−0.769	3	def	def	def	8.251	−2.543	−10	def	def	def
Monoclonal Antibodies	2.507	0.223	84	def	8.9	def	8.424	−0.649	102	def	def	def
Ribi ImmunoChem	0.364	−0.060	126	def	def	def	0.979	−0.478	7	def	def	def

a For three-month or 12-month period ending closest to Dec. 31. **b** Includes sales, contract research, royalty, and interest revenues. **c** Excludes extraordinary credits. **d** After-tax income as a percentage of sales. **def** = deficit.

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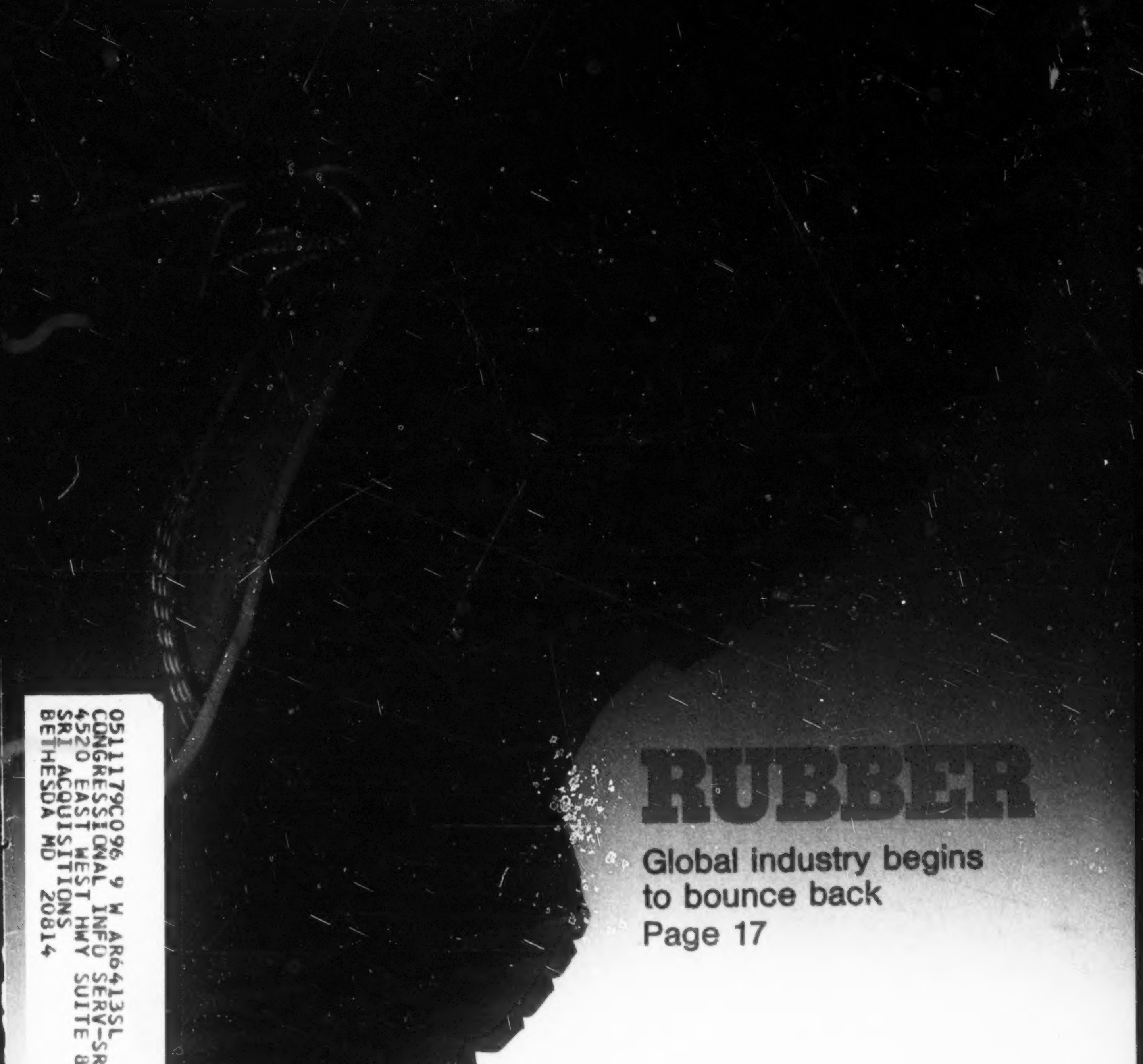
MARCH 31, 1986

CHEMICAL & ENGINEERING NEWS



RUBBER

Global industry begins to bounce back
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CHEMICAL & ENGINEERING
NEWS

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ISSN 0009-2347

MARCH 31, 1986

News of the Week

- **Indian government rejects Union Carbide's proposal to settle claims filed by Bhopal victims, questions rights of U.S. attorneys to represent them.** Page 4
- **Congress comes through with emergency funds to keep Superfund going through May 31.** Page 5
- **Justice Department to curb use of consent decrees to settle suits against the government.** Page 5
- **EPA fines Advanced Genetic Sciences $20,000 and suspends the firm's experimental use permit to test Frostban after company violates guidelines.** Page 6
- **Newly developed technique to grow epidermis cells may eliminate need to subject animals to toxicity tests.** Page 6

Cover: Shoe soles provide thriving market for rubber reinforced with silica and silicate pigments. Photo courtesy of Degussa

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Chemical firms' stocks outperformed Dow Jones Industrials Average 73% vs. 42% over past 52-week period. **Page 8**

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Research universities must streamline administrative procedures and pool resources to alleviate budget-cutting woes. **Page 11**

How research is funded has little impact on either the quality or the performance of the work, GAO reports. **Page 12**

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South Korean licensee for Unipol polypropylene process adds to a growing list of users of Carbide/Shell technology. **Page 15**

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Analytical chemists need to revise curricula and make better use of computers to improve status of the discipline. **Page 45**

ACS News

ACS comments to legislators on a number of issues—NSF funding, informing communities on chemical hazards, patents. **Page 47**

Product Report

The shakeout of the worldwide rubber industry that occurred when oil prices shot up in the 1970s has left a leaner, trimmer industry enjoying higher production and rising consumption. Page 17

Chemical Firms Continue To Ride Stock Market Surge

Performance of C&EN's chemical stock index outstripped Dow Jones Industrials Average over the past 52 weeks

David Webber, C&EN New York

The Dow Jones Industrials Average, the bellwether stock market index, has set so many records during the past year and a half, it was no surprise to many that it surpassed yet another milestone last Thursday when it reached 1804.24. From a year earlier, when the average stood at 1267.45, the Dow Jones Industrials measurement jumped a remarkable 42%, but that increase still fell far short of the 73% surge registered over the same period by C&EN's chemical stock index, which climbed to 377 last Thursday from 223 at the same time a year ago.

C&EN's chemical stock index is based on the performance of the common stock of American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Hercules, Monsanto, and Union Carbide, but the increase was even more widespread. Of the 15 largest chemical companies in terms of sales, the per-share price of 14 firms rose by a double-digit percentage. Only one company, International Minerals & Chemical, registered a decline in the price of its common stock, down 15% over the 52-week period.

Shares of many of the 15 largest chemical companies were selling at the close of trading on March 20 at or near their 52-week high-water marks. Air Products stock, for example, which has become the darling of many investment analysts of late, reached a 52-week high of $\$81\frac{1}{4}$ last week, up 67% from its year-earlier level. Also notching 52-week highs were shares of Dow Chemical, up 83% for the one-year period to $\$52\frac{7}{8}$, and Monsanto, up 52% for the same period to $\$65\frac{1}{8}$.

Other companies trading near the top of their 52-week ranges were American Cyanamid, up 37% from a year before to $\$70\frac{1}{8}$; Celanese, another Wall Street favorite, up 121% to $\$198\frac{1}{2}$; Hercules, up 42% to $\$45\frac{7}{8}$; National Distillers & Chemicals, up 37% to $\$40\frac{1}{2}$; Olin, up 28% to \$40; PPG, up 71% to $\$64\frac{1}{2}$; and Rohm & Haas, also up 71% to $\$105\frac{1}{2}$.

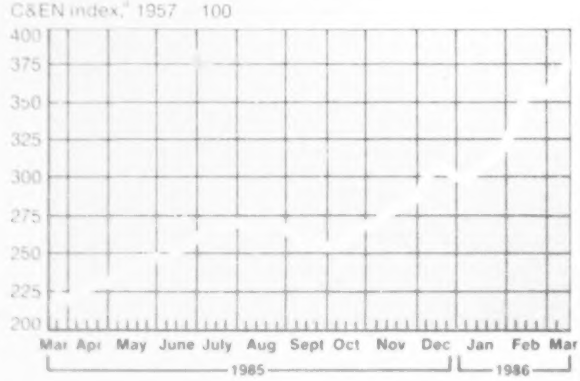
Union Carbide common stock split three-for-one at the beginning of March and closed last Thursday at $\$19\frac{3}{8}$, slightly below its high since the split of \$20 per share. The company also distributed to shareholders rights on a one-for-one presplit basis pegged to the value of Carbide's consumer products division, which the company intends to sell as soon as possible. Those rights have been trading separately on the New York Stock Exchange.

To calculate the stock's performance over the past year—a period during which the stock first started to recover from its post-Bhopal nadir and then took a ride on the rocket powered by GAF's abortive takeover attempt last fall—it is necessary to add the market value of

Major stock indexes have lagged the performance of chemicals

	March 20, 1986	March 22, 1985	% change
Dow Jones Industrials Average	1804.24	1267.45	42.4%
New York Stock Exchange Composite	136.13	103.65	31.3
New York Stock Exchange Industrials	155.76	119.09	30.8
American Stock Exchange Index	267.32	224.99	18.8
Over-the-Counter Composite	372.71	278.91	33.6
Over-the-Counter Industrials	372.97	297.63	25.3
Standard & Poor's 500	236.54	179.04	32.1
Standard & Poor's 400 Industrials	261.61	199.73	31.0
C&EN's chemical stock index	377	223	72.9

Chemical stocks gained 52% over the past 12 months



a C&EN weighted stock price index of American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Hercules, Monsanto, and Union Carbide

Many chemical stocks are trading near their 52-week high

Company	Latest price[a]	% change from a year ago	52-week range High	52-week range Low	Dividend yield[b]
Air Products	$ 81¼	67%	$ 81¼	$46⅞	1.8%
American Cyanamid	70⅛	37	72½	48	2.7
Celanese	198½	121	200	88⅛	2.4
Chesebrough-Pond's	43½	35	48½	31	4.6
Dow Chemical	52⅞	83	52⅞	28	3.4
W. R. Grace	51	25	57¼	35½	5.5
Hercules	45⅞	42	47⅜	31½	3.5
International Minerals	34⅞	−15	44	29¾	2.9
Monsanto	65⅛	52	65⅛	40⅝	3.8
Morton Thiokol	35⅞	22	40½	28⅝	2.0
National Distillers	40½	37	41½	26⅜	5.4
Olin	40	28	41¾	29⅛	3.8
PPG Industries	64½	71	65¼	34½	2.7
Rohm & Haas	105½	71	106	55¾	2.1
Union Carbide[c]	19⅜	56	20	7⅛	5.8

a As of close on Thursday, March 20, 1986. b Annual dividend as % of stock price. c Adjusted for 3-for-1 stock split and excluding market value of rights distribution.

the rights back into the market value of the common stock. On that basis, Carbide's market value (the product of the number of shares of common stock times the stock price plus the product of the number of rights times their price) amounted last Thursday to $6.78 billion, up 157% from the year-earlier market value of $2.64 billion. At that time, the per-share price of Carbide's common stock stood at $37⅜.

On that basis, Carbide's stock performance, once adjusted for comparability to a year ago, has been the best of any of the 15 largest chemical companies over the past 52 weeks. Even if the value of the rights is excluded, the price of a share of common stock, when adjusted for the three-for-one stock split, rose 56% over the 52-week span.

The rapid rise of C&EN's chemical stock index outpaced all the major stock market indexes. Chemical stock values rose more than twice as much during the same period as the New York Stock Exchange Composite index, up 31% to 136.13; the New York Stock Exchange Industrials index, also up 31% to 155.76; the Over-the-Counter Composite index, up 34% to 372.71; the Standard & Poor's 500 index, up 32% to 236.54; and the Standard & Poor's 400 Industrials index, which rose 31% to 261.61.

C&EN's chemical stock index rose nearly three times as much as the Over-the-Counter Industrials index, which climbed 25% during the 52-week period to 372.97, and nearly four times as much as the American Stock Exchange Index, which increased 19% between March 22, 1985, and March 20, 1986, to 267.32.

Some of the chemical stock index's exceptional growth over the past year is due to extraordinary circumstances. Part of the reason Carbide stock is so much higher on a percentage basis, for instance, is that it started the 52-week period near its post-Bhopal low. Carbide common stock closed the Friday before the Dec. 3, 1984, gas-leak disaster in Bhopal, India, at $48⅞. After the disaster, the per-share price dropped into the mid-30s, where it was languishing in March. The stock climbed back to slightly above the pre-Bhopal plateau during the summer, after which first rumors of and then an overt takeover bid by GAF brought the stock value up to $75 at the turn of the year.

The tremendous rise of Carbide's market value over the 52-week period markedly increased its impact on C&EN's chemical stock index. A year ago, Carbide's market value accounted for just 14% of the group's total market capitalization. As of March 20 this year, the company's market value, when adjusted to include the value of the rights distributed to shareholders, accounted for 21% of the 15 companies' total market capitalization.

Nonetheless, most chemical stocks have performed superbly over the past 52 weeks. Wall Street analysts, however, present a mixed forecast for the group during the coming months. Overall, they foresee a generally positive environment for the chemical industry for the remainder of 1986 because of such economic factors as declining interest rates and the falling value of the U.S. dollar, which means that foreign earnings will translate at higher levels and probably will mean that the depredations of imports in the U.S. market for commodity chemicals will be eased somewhat. Analysts also believe that chemical industry performance will be aided by trends such as the steady shrinking of commodity chemical capacity both in the U.S. and in Western Europe and by declining prices for raw materials and energy.

\On the other hand, Wall Street continues to worry about the stalled agricultural economy, which has had severe effects on the earnings performance of many chemical companies in recent quarters.

Behind IMC's stock price decline—the only company in the group of 15 largest chemical firms whose stock price fell during the past 52 weeks—was the agricultural slump, which has meant poor sales and prices for IMC's fertilizer products and thus poor earnings. In the fourth quarter of 1985, for instance, IMC net income declined 90% from a year earlier. Total 1985 net income of $55.2 million was 47% lower than in 1984. Nor is there any sign that performance will improve this year. In mid-February, the company lowered its earnings estimate for the fiscal year ending June 30 to somewhere in the range of 50 cents to 75 cents per share, down from the $1.00 per share forecast issued just two months earlier. Just two months before that, IMC had predicted that fiscal 1986 earnings would decline to about $2.50 per share. In the fiscal year that ended June 30, 1985, IMC earned $4.39 per share. In light of this tremendous darkening of the earnings outlook, IMC last month also slashed its quarterly dividend to 25 cents per share from 65 cents per share. ☐

Global Rubber Industry Resumes Growth Trend

Bruce F. Greek, C&EN Houston

After years of just plodding along, rubber producers throughout the world—and especially those in the U.S.—may well have something going for them. But the medicine has been bitter.

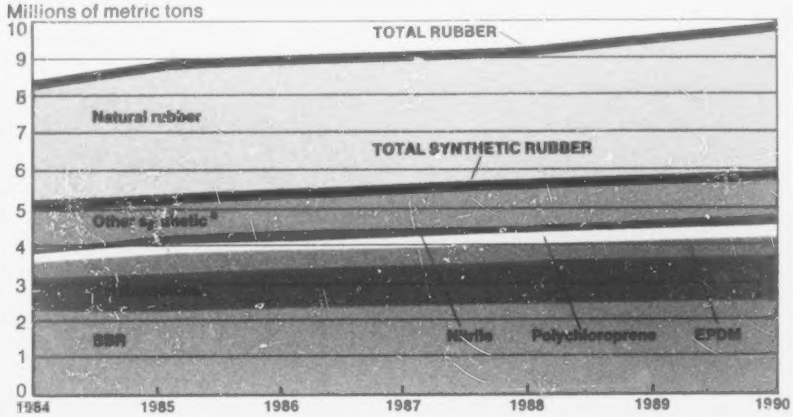
The oil shocks of the mid- and late 1970s sent many rubber producers into a tailspin. The rising costs of energy and feedstocks, coupled with the downsizing of automobiles and thus automobile tires and other automotive parts, conspired to limit producers' growth prospects, and when profits did materialize in the industry, they were minimal. As a result, producers of elastomers were forced to review operations, cut costs, and close down marginal plants. The resulting shakeout has left the rubber industry in perhaps a better position than at anytime in the past decade.

It remains to be seen, of course, whether producers will take advantage of their leaner operations, lower feedstock costs from falling oil prices, and a resurgent production situation.

After declining in recent years, production and consumption of rubber are rising again, at least in noncommunist countries, for which figures are compiled regularly. Combined consumption of new rubber in those countries this year is expected to exceed 9 million metric tons, according to the International Institute of Synthetic Rubber Producers (IISRP), using data compiled by its members, and the International Rubber Study Group. Production will follow consumption closely, with inventory building expected to be minor.

Of the total consumption of new rubber (elastomers) in 1986, a little more than 60% will be synthetic. The remainder supplied by natural

Demand to grow slowly for rest of decade



Note: For noncommunist countries only; carboxylated latex excluded. **a** Includes SBR latex, butyl, polyisoprene, and miscellaneous. **Source:** International Institute of Synthetic Rubber Producers

rubber will be up again slightly this year but appears to be leveling off.

Another 4.1 million metric tons of new rubber will be consumed by the various communist countries of Eastern Europe, China, and Asia. More than 78% of this consumption will be synthetic rubber, IISRP estimates. Only in the China/Asia countries will natural rubber dominate with more than 61% of an estimated 750,000 metric tons of consumption.

Because synthetic rubber is a larger proportion of the total rubber consumed in communist countries than in noncommunist countries, worldwide consumption of rubber will be nearly 66% synthetic in 1986. That's about the same as in 1985 but down slightly from 1984. In the long run, little change is expected in the pattern of world consumption, because synthetic's share in communist countries will hold at about 78%.

In noncommunist countries so far in the 1980s, natural rubber, ethylene-propylene-diene monomer (EPDM), and several smaller-volume synthetic rubbers have made inroads in relative share of total consumption largely at the expense of styrene-butadiene rubber (SBR). Other big-volume synthetic rubbers, such as polybutadiene (solution type), polychloroprene, nitrile, and butyl, have held onto their shares of the market.

As perhaps might be expected of the oldest large-volume synthetic rubber, the demand for SBR is cyclical. For the rest of the 1980s, it is expected to be on the upward part of the cycle. According to IISRP data, as recently as 1979, total demand for SBR as solid and latex reached 3.4 million metric tons in noncommunist countries. Demand dropped to about 2.4 million metric tons in 1985, however. If the subsequent slow recovery continues, 1990 demand will be slightly more than 2.6 million tons, IISRP believes.

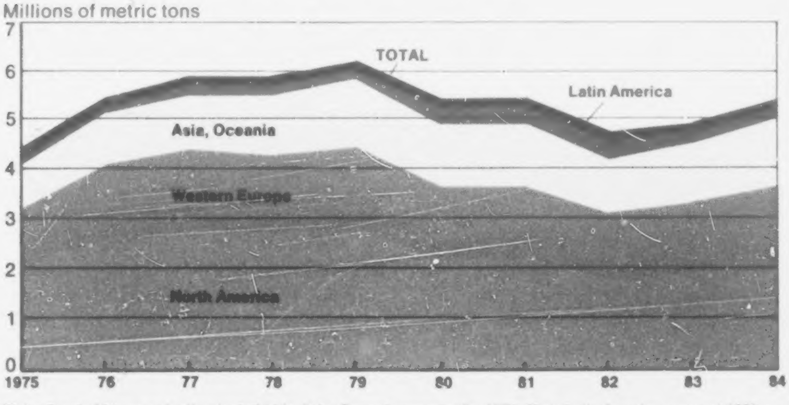
In noncommunist countries, capacity to make SBR far exceeds demand, an unfortunate fact equally true for some of the other synthetic rubbers. SBR capacity in 1985 was some 5.15 million metric tons, according to IISRP estimates. Plants, therefore, operated at an average rate of barely over 50% of capacity. At present, some capacity may be in a shut-down, inoperable state, but not yet officially scrapped.

By keeping its consumption ahead of that of natural rubber, SBR maintains its title of workhorse of the rubber industry in North America. But SBR's position is threatened by the increasingly severe service requirements that fabricated rubber products are now expected to meet. Many of SBR's physical properties are poorer than those of natural rubber and of other synthetic rubbers, particularly specialty rubbers with developed niches and use patterns. However, compared with the widely fluctuating prices of natural rubber, the price of SBR is relatively low and quite stable. This gives SBR a very strong economic advantage. Therefore, on a cost-performance basis, SBR will get the nod more often than not.

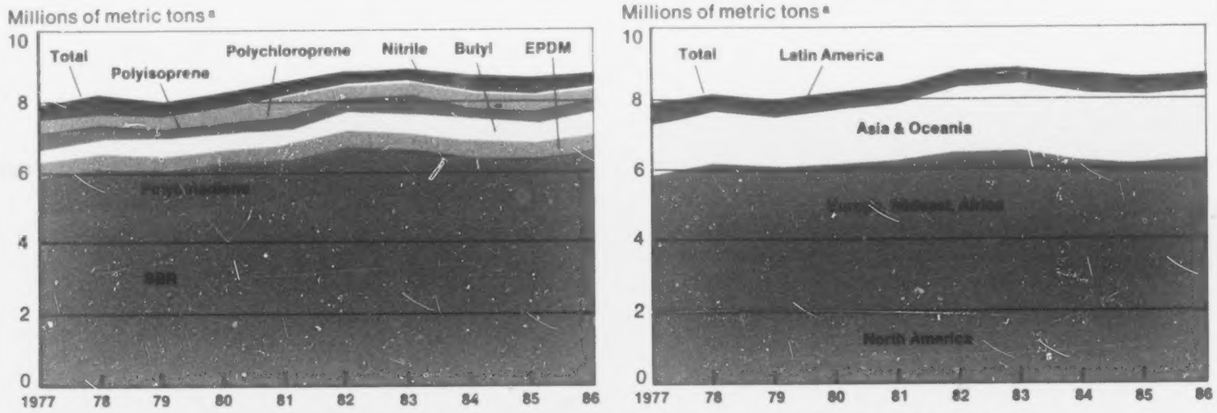
During 1985, however, U.S. SBR producers faced difficulties as production declined 16% to 804,840 metric tons, according to the Rubber Manufacturers Association (RMA). That amount was not much more than half the 1.54 million metric tons produced in the U.S. in 1973.

During the past two years, U.S. SBR capacity has held steady at about 1.04 million metric tons, with a small amount of that capacity shut

Synthetic rubber production in noncommunist countries continues moderate recovery



Note: South Africa production included in Asia, Oceania segment for 1975–79; in Latin America segment 1980–82; and in North America segment 1983–84. **Source:** International Institute of Synthetic Rubber Producers



Synthetic rubber capacity peaked in 1983 . . .

. . . declining in North America but growing in some other areas

a Noncommunist countries only; excludes specialty rubbers but includes carboxylic latex. **Source:** International Institute of Synthetic Rubber Producers

down in 1985. The operating rate of U.S. plants in 1985 was about 81% of nameplate capacity. That relatively high operating rate results from a series of shutdowns and scrappage of some plants during the early 1980s that removed about a third of capacity. If forecasts for very slow growth for SBR during the rest of this decade are accurate, and if no additional SBR capacity is shut down, producers can expect the operating rate to increase only modestly for some time.

Tires and tire components such as tread rubber consume more than 70% of SBR produced in the U.S. The share of consumption going into tires and components has been rising since the late 1970s—even though consumption of SBR in tires dropped about a third. Unfortunately, the amount of SBR consumed by nontire uses has declined even faster, dropping by more than half during the same period. The reduction in the amount of SBR used in tires stems from changes in the size and type of tires—largely a shift to radials—sold in recent years. The decline in demand in nontire uses results from the need for elastomers that meet tighter specifications.

The decline in SBR's use in tires and tire components could be slowing and may end by the early 1990s. Depending on the way crude oil prices go during the rest of the 1980s, the shift to smaller, lighter cars, either produced domestically or imported, and the shift to longer-lived radial tires for all kinds of passenger cars could slow drastically. However, changes started years ago have some momentum and could continue. During the rest of this decade, industry sources forecast that the share of sales held by small cars likely will remain the same or even increase marginally. Because of competition and consumer demand, sales of bias-ply and bias-belted tires also will remain high.

Some further shift toward radial truck tires will continue, but this shift is forecast to have only a minor impact on SBR. Rising imports of tires could force a continuing decrease in U.S. passenger tire production and accelerate the decline in U.S. SBR consumption. Tire exports from the U.S., which already are small, are continuing to shrink, further eroding U.S. consumption of SBR.

These factors affecting SBR consumption have been at work for more than a decade. They have had a direct impact on tire production, causing a decline in production of most kinds of tires and causing tire-making plants to be closed. Tire mileages, which increased 100% or more during the decade, influenced this decline most. However, radial tires reduce SBR demand still further because less SBR is used in radials than in the earlier bias-ply and bias-belted tires. Radial tire sidewalls have a much higher natural rubber content because of a need for properties such as resilience, aging stability, and building tack (adhesiveness needed to keep the various parts of a tire together during its assembly). Use of SBR in tire treads—usually blended with polybutadiene to increase abrasion resistance and add to tire life—has not changed much. The percentage of SBR and other synthetic rubbers has declined to betweeen 60 and 65% in radial tires from more than 85% in older-style tires. Moreover, smaller tire sizes, on average, have reduced the amount of new rubber going into tires and tire components.

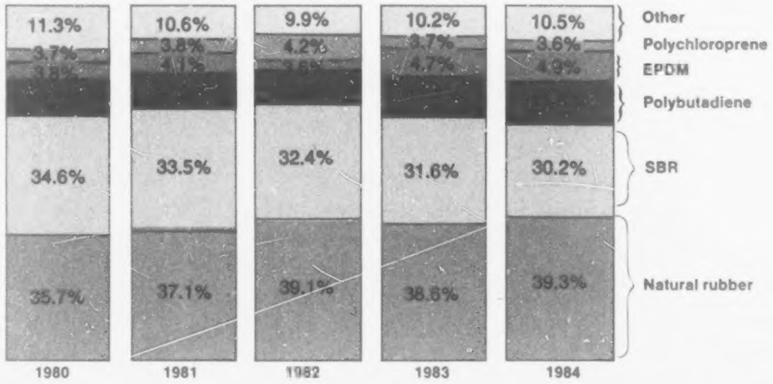
Owing to their size, truck tires, though produced in much smaller numbers, require large amounts of rubber. Historically, heavy-duty truck tires have contained larger fractions of natural rubber than are used in passenger and light-truck tires, because they require high resistance to heat and wear under heavy loads. Radial heavy-duty truck and bus tires account for about a third of total truck tire production, whereas radial passenger car tires are three quarters or more of automobile tire production. According to forecasts, the shift to a higher percentage of radial truck tires will occur more slowly than it has for passenger car tires and will affect SBR consumption more slowly as well.

Many other kinds of tires, for uses ranging from aircraft to utility trailers, require a wide variety of rubber compositions. The quantities of such tires produced are small, and

CIRCLE 16 ON READER SERVICE CARD →

Natural rubber use increased in early 1980s

% of total shipments[a]



[a] For noncommunist countries only. **Source:** International Institute of Synthetic Rubber Producers

total new rubber consumed in them also is small. Even with a resurgence in demand for huge tires for earth-moving equipment as road building and repair increase, changes in miscellaneous tire production will not have a large effect on demand for rubber and for SBR.

The nontire uses of solid and latex forms of SBR are dominated by automotive uses, mechanical goods, and carpet backing. All of these markets have declined because of higher performance requirements for the fabricated forms. The decline has slowed, however, if for no other reason than that the base has become small. The cost/performance factor remains important to use of SBR, helping it to compete against other rubbers that perform better but cost much more.

In the U.S., solution-polymerized *cis*-1,4-polybutadiene takes second place to SBR in share of synthetic rubber consumption. Apparent 1985 consumption was 374,200 metric tons, according to RMA figures, down 9% from 1984. Production in 1985 was down more than 8% to 329,450 metric tons. A modest 7% increase in imports accounted for the rest of the supply. Imports, at nearly 70,000 tons last year, have continued to increase significantly during the 1980s.

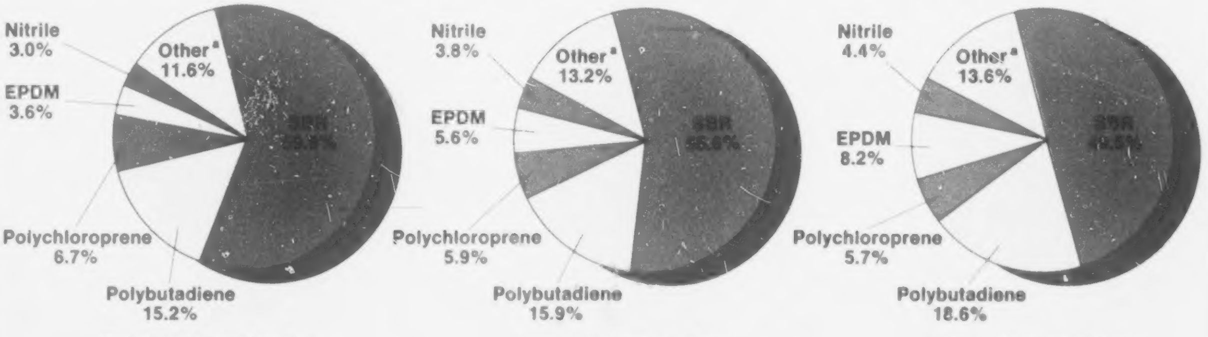
Capacity to make polybutadiene in the U.S. totals about 425,000 metric tons and has not changed much during the past two years. The operating rate of polybutadiene plants last year was about 78%. Other than debottlenecking, no capacity additions for polybutadiene are forecast for this year or next. Operating rates could increase this year and later on. The decline in crude oil prices would tend to favor use of heavier feedstocks such as gas oils in steam crackers that make olefins, thereby raising butadiene production and probably significantly lowering its cost to polymer producers. Lower-cost polybutadiene produced in the U.S. could slow imports and slightly shift consumption away from natural rubber.

Worldwide, tires and tire products consume more than 77% of the total polybutadiene output, whereas they consume smaller percentages of other kinds of rubber, according to IISRP data. In North America, more than 80% is used in tires. In the past, the tire uses accounted for an even higher fraction, but slower growth in tires than in high-impact polystyrene and mechanical goods has cut into the tire share.

Polybutadiene's major tire use is in treads, for which it provides long wear and less resistance to rolling than most lower-cost elastomers. Its major drawback is its poor wet-skid performance. As a result, polybutadiene is blended with SBR and natural rubber in varying amounts, depending on the kind of tire being made. Passenger car tire treads generally are blends of polybutadiene and SBR, whereas truck and bus tire treads are blends of polybutadiene and natural rubber.

The outlook for growth of polybutadiene in tires will follow that

Smaller-volume specialty rubbers gain share of total world production at expense of SBR



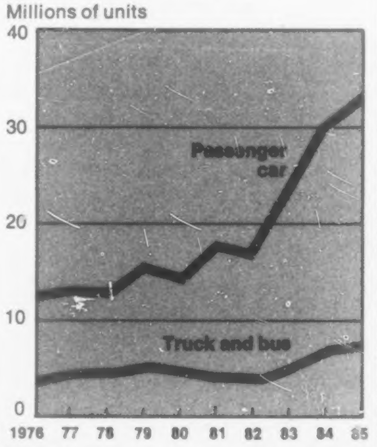
Total 1975 production = 4.3 million metric tons

Total 1979 production = 6.2 million metric tons

Total 1984 production = 5.4 million metric tons

Note: Noncommunist countries only. [a] Includes polyisoprene, butyl, and all others such as specialties; latices included with individual rubbers.
Source: International Institute of Synthetic Rubber Producers

Imports of tires into U.S. continue to surge



Sources: Department of Commerce, C&EN estimates

for tire demand. No significant changes are expected in the composition of polybutadiene blends. Increased production of radial tires also will have little effect on demand for polybutadiene in tires. Declines in the value of the dollar, which may reduce finished tire imports, probably have more influence than other factors over polybutadiene demand in tires.

Rubber-modified polystyrene and use in mechanical goods account for the remainder of polybutadiene consumption. Addition of polybutadiene and some other elastomers to polystyrene improves impact resistance of the final resins. Higher percentages of polybutadiene, as much as 10% of the total resin, increase impact resistance. These resins are used largely in various consumer and recreational products. Consequently, growth in demand for polybutadiene as a modifier of polystyrenes will depend on growth of these consumer products. This growth is cyclical because it is influenced by fashion, but likely will average 5% annually over the rest of the 1980s.

Mechanical goods require relatively small quantities of polybutadiene. Demand growth for polybutadiene for such items is forecast to be more than for that in tires, but less than that for modifying polystyrene. Longer term, this use will have little effect on consumption.

Other elastomers—such as emulsion-polymerized cis-1,4- material, the trans-1,4- form, and various widely modified polymers—are made of butadiene. Both production and consumption of such rubbers are small. End uses are specialized, so growth varies but will not make those rubbers large-volume materials before the 1990s.

Ethylene-propylene (EP) elastomers have become the third-largest-volume rubber in the U.S. And the elastomers' worldwide production may have surpassed that for butyl rubber. But, because in some countries only one company produces butyl rubber, no figures are available that separate butyl production on a worldwide basis from the "all-other" category. Output of EP rubber in noncommunist countries

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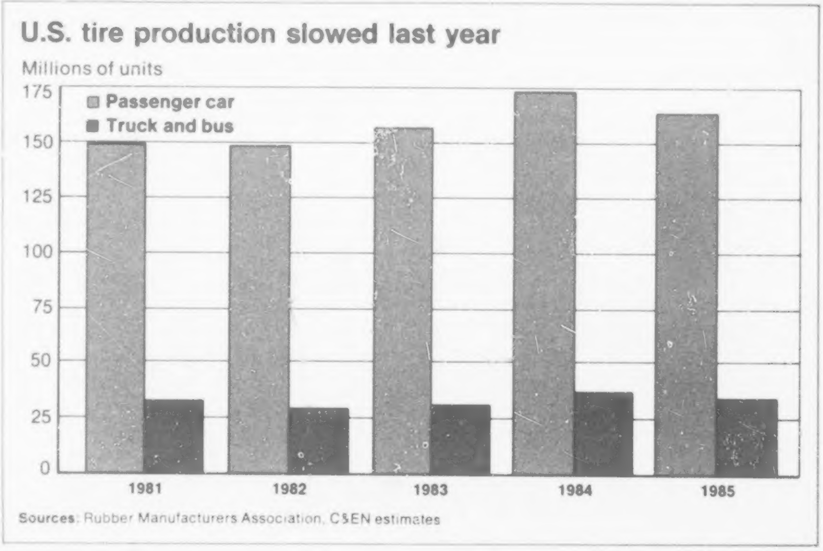
reached 430,000 metric tons in 1984, according to IISRP data. In the U.S., 1985 production was 214,800 metric tons, almost the same as 1984 production, or roughly half the world production, according to RMA. Exports of EP rubber increased more than 14% last year to almost 38,500 tons, one of the few rubbers, and the only large-volume one, to show an increase in exports.

During the past two years, capacity to make EP rubber—both the copolymers and terpolymers (EPDM)—has been rising slowly and totals more than 260,000 metric tons. Some capacity additions, as well as debottlenecking of existing capacity, are under way. These could add as much as 10,000 tons to U.S. total capacity by the beginning of 1987. If 1986 production of EP rubber is 220,000 tons, as some forecast, the existing capacity will be operated at about 85% of nameplate, or possibly slightly less as expansions come on stream.

Historically, production of EP rubber in the U.S. has been cyclical, reaching new peaks during economic expansions and falling significantly during recessions. The causes of these cycles vary. During the early commercial production that began in 1961 but grew slowly until 1964, this rubber was used largely by the automotive industry as a tire rubber and in mechanical goods. Problems in its use during tire manufacture led to declines in this use during the 1970s and to a realization among producers that tires would not become a major use. As a result, producers have worked to improve production processes to lower costs and to improve quality. Also, they have found many new uses for EP rubber, most of which are in consumer durables and subject to economic cycles.

Relatively small amounts of EP rubber now go into tires, and most of that is used in tubes and in the white sidewall stripe for passenger car tires. Other automotive uses trended downward as U.S. car production declined in the early 1980s. Car sizes also declined, causing such parts as hoses, belts, and door seals and other weather stripping to be downsized as well. Competition from other rubbers also keeps up the pressure for possible shifts. Thus, the longer-term growth rate for use of EP rubber in automobiles is predicted to be low.

About 75% of EP rubber goes into nonautomotive uses, the largest five of which are wire and cable coverings, modification of polymers, single-ply roofing, oil additives, and some thermoplastic elastomers. A large miscellaneous group of uses, however, ranks second to automotive uses in the U.S.


U.S. tire production slowed last year

Sources: Rubber Manufacturers Association, C&EN estimates

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Specialty elastomers have a number of important uses

Specialty elastomers are produced with a wide variety of physical properties. Most are expensive. Many have high growth rates from small bases. Some are produced in tiny volumes. Larger-volume examples include:

Acrylics. These elastomers, most often made of ethyl-, butyl-, or methoxy and ethoxy ethyl acrylates, have good heat and oil resistance. As a result, their major uses are in seals, gaskets, and hoses. They sell at about \$2.50 per lb. U.S. annual consumption is less than 10 million lb. Major U.S. producers are American Cyanamid, Du Pont, and B. F. Goodrich Chemical.

Chlorosulfonated polyethylenes. Crystalline polyethylene that is modified by chlorine and sulfonyl groups has toughness; high resistance to ozone and light; and good resistance to oxidation, heat, oil, and corrosive materials. A wide variation in compounding and curing allows use as wire and cable coverings, roofing, automotive parts, pond liners, hoses, and belting. Most types of this elastomer sell for less than \$2.00 per lb. Consumption this year may reach 60 million lb. Du Pont is the major U.S. producer.

Copolyester ethers. Polymers in this group result from condensation of polybutylene terephthalates and polytetramethylene ether glycol terephthalate. They have high strength, abrasion resistance, good resistance to chemicals and petroleum, and a relatively wide useful temperature range. Some 20 million lb of these elastomers may be used in 1986 as hose, wire and cable coverings, as well as in various automotive parts. Selling prices range from \$2.00 to \$3.00 per lb. Major U.S. producers are Du Pont, GAF, and General Electric.

Epichlorohydrins. Homo- and copolymers of epichlorohydrin are fabricated into elastomeric products that have low gas permeability, good resistance to petroleum products, and low-temperature flexibility. Most of the 15 million lb consumed in the U.S. will go into automotive products such as gaskets, hoses, and motor mounts. Selling prices are more than \$2.00 per lb. B. F. Goodrich Chemical and Hercules are the major U.S. producers.

Fluorinated polymers. Fluorine-containing polymers, made of C_2 and C_3 fluoro-olefins, have good resistance to heat, chemicals, and weathering, and good mechanical properties. About 5 million lb of these expensive elastomers, which can sell for more than \$15 a lb, will go to severe-service uses as seals, gaskets, hoses, and other items in automotive, oil-well drilling, and other industries. Sizable producers are Du Pont, Ethyl, and 3M.

Polysulfides. Oldest of the specialty elastomers, these materials have good resistance to ozone, oxygen, sunlight, and swelling caused by chemicals. They have low permeability to gases and liquids, and good low-temperature properties. About 20 million lb are expected to be consumed in 1986, largely as sealants. Prices are about \$2.00 per lb. Morton Thiokol is the major U.S. producer.

Silicones. With a backbone of silicon and oxygen, these elastomers are known for their resistance to ozone, weathering, and hydrocarbons. Various side groups added to the chain can give other properties. Most of the approximately 75 million lb expected to be consumed in 1986 will go into sealants and adhesives, with smaller quantities used in automotive parts, wire and cable coverings, and medical equipment. Prices range higher than \$2.50 a lb with very special types for medical uses priced at more than \$100 per lb. Major U.S. producers are Dow-Corning and General Electric.

Thermoplastic block copolymers. Most of these rubbers are based on polystyrene and polybutadiene with a wide variety of types available for diverse uses. More than 250 million lb will go into adhesives, coatings, shoe soles, other polymers as modifiers, toys and other consumer products, as well as other fabricated products. Prices range from 50 cents to \$2.50 per lb. Shell Chemical is the major U.S. producer.

Urethanes. These elastomers are known for high abrasion resistance and strength. Major uses are in such items as wheels for industrial trucks, seals of various kinds, adhesives, and fibers. Consumption could reach 175 million lb this year. Selling prices range from about \$1.00 to \$2.00 a lb. Among important U.S. producers are American Cyanamid, Dow Chemical (Upjohn), Du Pont, Mobay, and Uniroyal.

Of all the EP rubber uses, single-ply roofing made mostly of EPDM now gets the most attention because its production grew so fast over the past decade, from practically nothing to about 30,000 metric tons this year. The ozone and weathering resistance of EPDM spurs this use, as do other advantages such as its lighter weight, lower cost of installation (compared with built-up roofs), and its suitability for use over heat-sensitive expanded polystyrene or polyurethane foam insulations. Now, with problems of seam adhesion and flashing components solved, both new and replacement roofing of this elastomer are well established. However, growth in this use of EP rubber—almost all EPDM—will probably slow because of the larger size of the base, reduced industrial building, and competition from some elastomer-modified asphalt or bitumen products.

Use of EP rubber in thermoplastic olefin elastomers has had a high growth rate. These elastomers are blends of the rubber and a polyolefin (most often polypropylene) and are sometimes crosslinked. They go into many nontire automotive items such as exterior body and bumper parts, hoses, gaskets, and dashboard parts. In addition, those elastomers are used in severe-service wire and cable coverings and molded items. Because of several new developments, growth forecasts for olefin elastomers are high—about 10% a year.

The wide range of commercial uses of EP elastomers and their substantial export demand combine to give these rubbers one of the better demand forecasts at this time in the U.S. Because a large fraction is produced in the U.S., world production of the materials also has been cyclical, but has continued to increase at good rates.

Worker taps rubber tree at Goodyear's Dolok Merangir plantation in Sumatra

Other smaller-volume rubbers have not had the swings in production that EP rubber has had, but their production has trended downward. For polyisoprene, polychloroprene, and butyl rubbers, for instance, 1984 world production ranged from levels that barely matched previous production highs to levels well below these. World production of polyisoprene in noncommunist countries totaled 146,000 metric tons in 1984, well below the peak of 242,000 tons in 1979, according to IISRP. Output of nitrile, on the other hand, was 238,000 metric tons in 1984, just barely below its all-time production high of 239,000 tons also in 1979.

The capacity situation for polyisoprene is unusual. Estimates for Eastern Europe, including the U.S.S.R., total about 950,000 metric tons, more than twice the capacity of the rest of the world, which is less than 390,000 tons. Industry sources suggest that in Eastern Europe, polyisoprene capacity and utilization of that capacity are high to minimize dependence on natural rubber supplies. That explanation is consistent with the relatively large fraction of synthetic rubber out of total rubber consumed in communist countries, or more than 78% of the total in 1985, according to IISRP.

Polyisoprene in the cis-1,4- form has properties and chemical structure closer than any other rubber to the widest produced form of natural rubber, *Hevea brasiliensis*. Therefore, it can be used interchangeably with natural rubber in most applications. The trans-1,4- form mirrors two other natural rubbers, gutta blata and gutta percha. All three of these rubbers have properties very different from those of *cis*-1,4-polyisoprene, either natural or synthetic. The trans-1,4 forms- are made in small quantities worldwide and are used in products for which high tensile strength and abrasion resistance are important.

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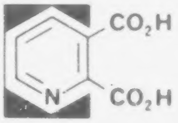

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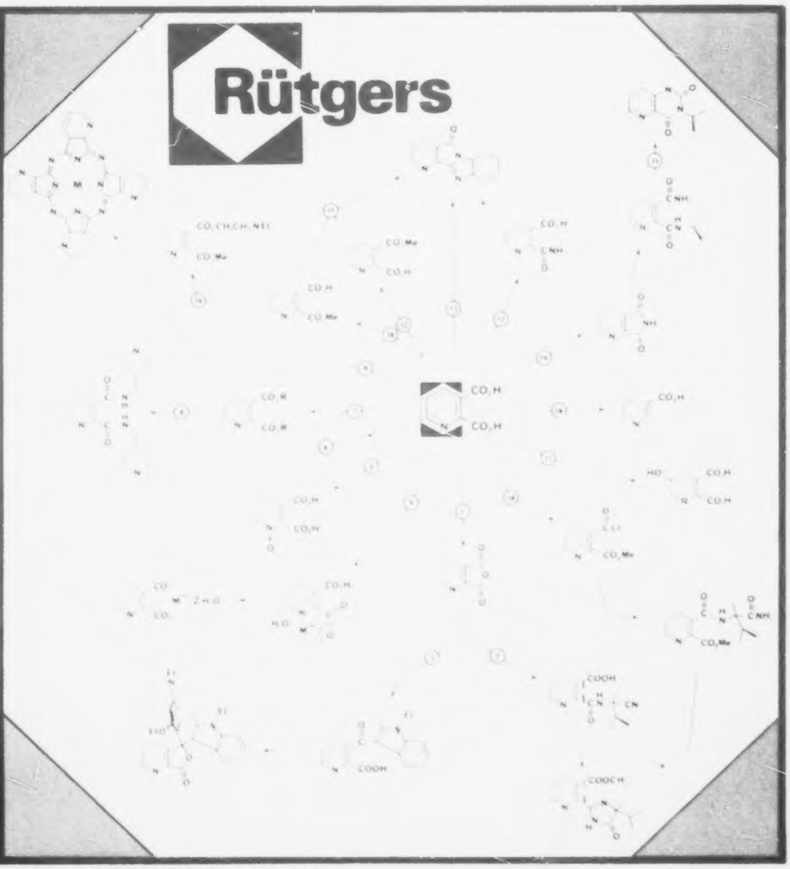
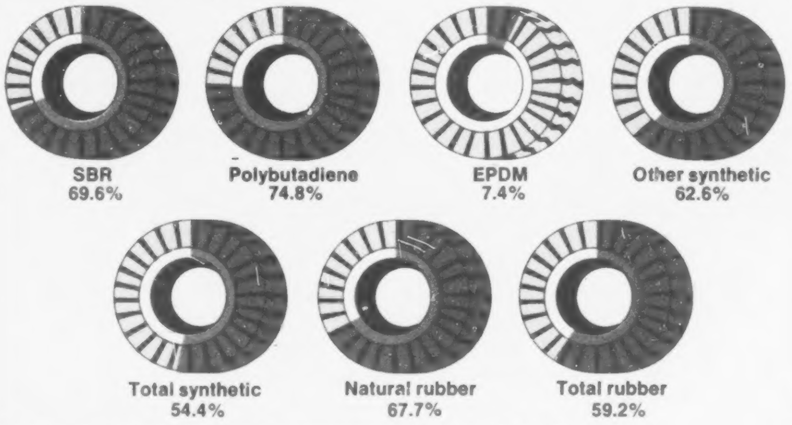


CIRCLE 18 ON READER SERVICE CARD

Tires and tire products take well over half of world's rubber consumption



Note: Noncommunist countries only. **Source:** International Institute of Synthetic Rubber Producers

U.S. consumption of synthetic *cis*-polyisoprene has fallen to about half the peak annual consumption of more than 100,000 metric tons in the early 1970s. Relatively lower prices for natural rubber and increased raw material costs for making synthetic polyisoprene prompted this decline and reduced the number of U.S. producers to one—Goodyear. Because the cost of direct manufacture is high, supply of the monomer has become limited to that recovered from product streams of catalytic and steam cracking.

Tires consume more than half of polyisoprene output. The amount used in tires is about equally divided between passenger car and truck and bus tires. A much higher fraction of polyisoprene is used in truck tires because of its high resistance to wear and heat buildup under heavy loads. Growth in tire use likely will continue at a slow pace and will depend on the usual factors of cost competition with other rubbers, general demand for tires, size of tires, and the speed of the shift to radial-ply construction for truck and bus tires.

In polyisoprene consumption, various mechanical goods are a distant second to tires. Other uses are in footwear soles, rubber bands and erasers, hoses, consumer and medical products, and sealants. With natural rubber constantly looming as a potential replacement for polyiso-

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prene in all these uses, polyisoprene's growth depends heavily on cost competition, and that depends on monomer cost. If crude oil prices remain much lower than in 1985, more naphtha and gas oil will be cracked for making olefins in steam crackers and fluid catalytic cracking units, thereby raising output of isoprene and lowering its cost.

Polychloroprene production has followed a pattern similar to that of polyisoprene. In 1984, total production in noncommunist countries was about 313,000 metric tons, down less than 12% from production in 1979. U.S. production in 1984 was 130,000 metric tons, down 29% from 1979 production. Two major U.S. producers, Denka Chemical and Du Pont, have a combined capacity of a little less than 170,000 metric tons.

U.S. exports of polychloroprene, down about 5% in 1985, were more than 41,000 metric tons, making exports the largest outlet for U.S. production. Imports totaled more than 2000 metric tons in 1985, leaving apparent consumption at about 90,000 tons. Because prices of polychloroprene are well above $1.00 per lb at producing plants, consumption is limited to those applications for which this rubber will meet the service requirements.

Copolymer Rubber & Chemical Corp. EPDM plant at Addis, La.

Polychloroprene is not a tire rubber. Its major end uses are in mechanical goods for severe service in industry and in autos and trucks. Its high strength and resistance to abrasion, hydrocarbons, and aging contribute to its growth prospects. On the other hand, high cost and difficulties in processing the rubber into fabricated items tend to limit its growth.

Nitrile is another nontire rubber of significant commercial importance. Noncommunist countries produced some 238,000 metric tons of it in 1984, down slightly from the record production of 239,000 metric tons in 1979, according to IISRP. U.S. production in 1985 was down 19% from 1984 to 54,500 metric tons, as reported by RMA. U.S. imports in 1985 dropped slightly to 11,500 metric tons, but exports declined more than 21% to 6700 metric tons, with a net apparent consumption of 60,300 metric tons.

Nitrile is a copolymer of acrylonitrile and butadiene. Its properties are influenced by the composition of the polymer. In general, the higher the acrylonitrile content, the higher the rubber's resistance to hydrocarbons, abrasion, and gas permeation. Rubber with low acrylonitrile content has better low-temperature and resilience properties. Extensive compounding is required to give fabricated nitrile rubber products adequate resistance to ozone

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and oxidants. Major uses include hoses, gaskets, seals, and many other mechanical goods. Because of nitrile rubber's resistance to hydrocarbons over a wide range of temperatures, growth in demand depends heavily on industrial operations and automotive output. Its cost is relatively high at more than $1.00 per lb, which tends to limit growth. Competition is strong from other elastomers that can withstand severe service.

Because of its impermeability to air, butyl rubber, another of the smaller-volume elastomers, is used mainly in tires. No data are available on worldwide or U.S. production of butyl rubber because there are so few producers. C&EN estimates that noncommunist countries produced 400,000 metric tons of butyl in 1984. No breakdown is possible between production of regular butyl (a copolymer of isobutylene and small quantities of isoprene) and the two halogenated butyl rubbers (chloro- and bromo-). U.S. output of all butyl rubber during the past three years probably averaged 150,000 metric tons per year. Imports of butyl have been rising, whereas exports, which are no longer reported, apparently have been falling. The net of imports over exports is estimated at 40,000 metric tons per year, suggesting U.S. consumption approaches 200,000 metric tons per year.

IISRP estimates world capacity to make butyl rubber at 690,000 metric tons, with 110,000 metric tons of the total located in communist countries. Exxon Chemical has more than 200,000 metric tons of annual capacity in the U.S. for all forms of butyl, and Polysar has 120,000 metric tons of capacity in Canada.

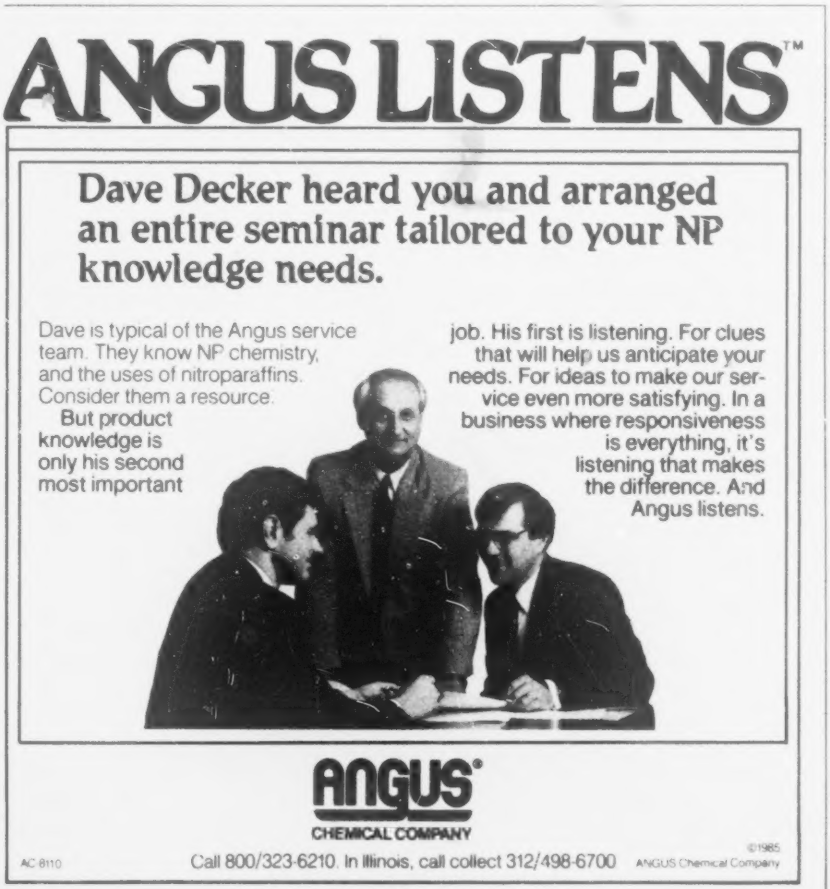
About 75% of U.S. consumption of butyl rubber goes into tires, mostly as inner liners for tubeless tires and tubes. Mechanical goods and sealants take most of the remainder. Prospects for growth in butyl rubber use, therefore, depend on tire demand and size, as they do for SBR and polybutadiene. As a result, growth in butyl rubber is expected to be slow but steady.

For many types of synthetic rubber, stiff competition comes from natural rubber. Natural rubber makes up a larger part of total rubber consumption than does any individual synthetic rubber and accounts for a little more than 39% of the noncommunist countries' total rubber supply, based on 1984 figures from IISRP. Because tire use dominates consumption with more than 71% going into tires and tire products in 1984, growth in demand for natural rubber will be slow.

No significant quantities of natural rubber are produced in the U.S. Although tiny amounts of guayule rubber are produced experimentally from this bush, which grows best in arid areas of the Southwest, almost all natural rubber consumed in the U.S. is imported. In 1985, U.S. imports of natural rubber totaled more than 789,000 metric tons, according to RMA. That represents a 1% decline from 1984—the recent historical high for natural rubber imports. Three countries—Indonesia, Malaysia, and Liberia—supply the dominant share of natural rubber consumed in the U.S.

In the U.S. apparent consumption of natural rubber in 1985 was 751,200 metric tons, according to RMA. Apparent consumption of SBR in 1985 was 838,400 tons, or about 87,000 tons more than natural. The decline in consumption of SBR has been faster than the growth in consumption of natural rubber. This suggests that the U.S. is becoming more dependent on imported natural rubber. Demand for rubber in the U.S. declined in 1985 about 6.5%, confirming the change in the position of natural rubber relative to synthetic.

Improvements in natural rubber quality and lower prices are given as the biggest reasons for increased U.S. use of natural rubber and for the general increase outside communist countries. About 20 years ago, a concept known as technically specified rubber (TSR) was developed for natural rubber. The quality of the various grades of TSR



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is determined by technical specifications rather than by visual observations used in determining quality of ribbed smoked sheets (RSS), which are the next largest volume of natural rubber in world commerce. TSR has more uniformity in its composition, is cleaner than RSS, and is formed into and shipped in palletized blocks similar in size to blocks of synthetic rubber produced in most U.S. plants. TSR now dominates imports of natural rubber into the U.S., but No. 1 RSS remains the basis for reported prices. Current prices are about 42 cents per lb for No. 1 RSS delivered in New York, which is well down from more than 70 cents per lb in 1980.

Quality improvements are not limited to natural rubber. All of the synthetics have been improved vastly since their commercial production began. The demand for better quality elastomers to meet ever more stringent requirements for use in harsh environments has caused development of a host of specialty rubbers. There is no compilation of all of the specialties, because of problems of definition and of commercial significance. Considerable overlap exists among the many properties of the various specialty rubbers available commercially. The cost vs. performance factor of each specialty rubber determines whether it will be used.

The specialty rubbers are more expensive than the big-volume general-purpose rubbers. Selling prices of specialties begin at double the price of SBR and keep rising. As a result, production in the U.S. of all of the specialties probably doesn't exceed 100,000 metric tons—less than 5% of total synthetic rubber production. Two of the specialty rubbers, silicone and chlorosulfonated polyethylene, could account for half of total specialty production this year. Production data on the specialties are limited, because most of the specialties made in any quantity have very few producers.

A large fraction of the world's nitrile production is used in hoses

Consumption data are even more limited. Fabricated products usually are mechanical goods such as gaskets and other automotive parts, various kinds of industrial and automotive hoses and belts, wire and cable coverings, sealants, sheet material, and myriad miscellaneous uses. Because of their properties such as high resistance to ozone, oxidation, temperature extremes, chemicals, hydrocarbons, and weathering, specialty rubbers go into these fabricated products. Considerable substitution of one specialty rubber for another occurs, however, as properties are improved and costs decrease.

The specialty rubber industry receives more attention than its size warrants, owing to its fast growth, capture of uses from nonrubber materials, and apparent high profitability. But the big-volume synthetic rubber producers also are moving ahead. In recent years, most large rubber producers have begun statistical quality and process control programs to minimize product variation and improve quality. They have done well in reducing their processing costs and in improving the quality and consistency of their products.

The higher-quality rubber produced by the big-volume synthetic rubber producers has resulted in improved quality of fabricated rubber products, and in lower costs of manufacturing. This unfortunately has reduced demand for the various types of synthetic rubber. With streamlining and development, the synthetic rubber industry in the U.S. may have become smaller, but it also has become better. □

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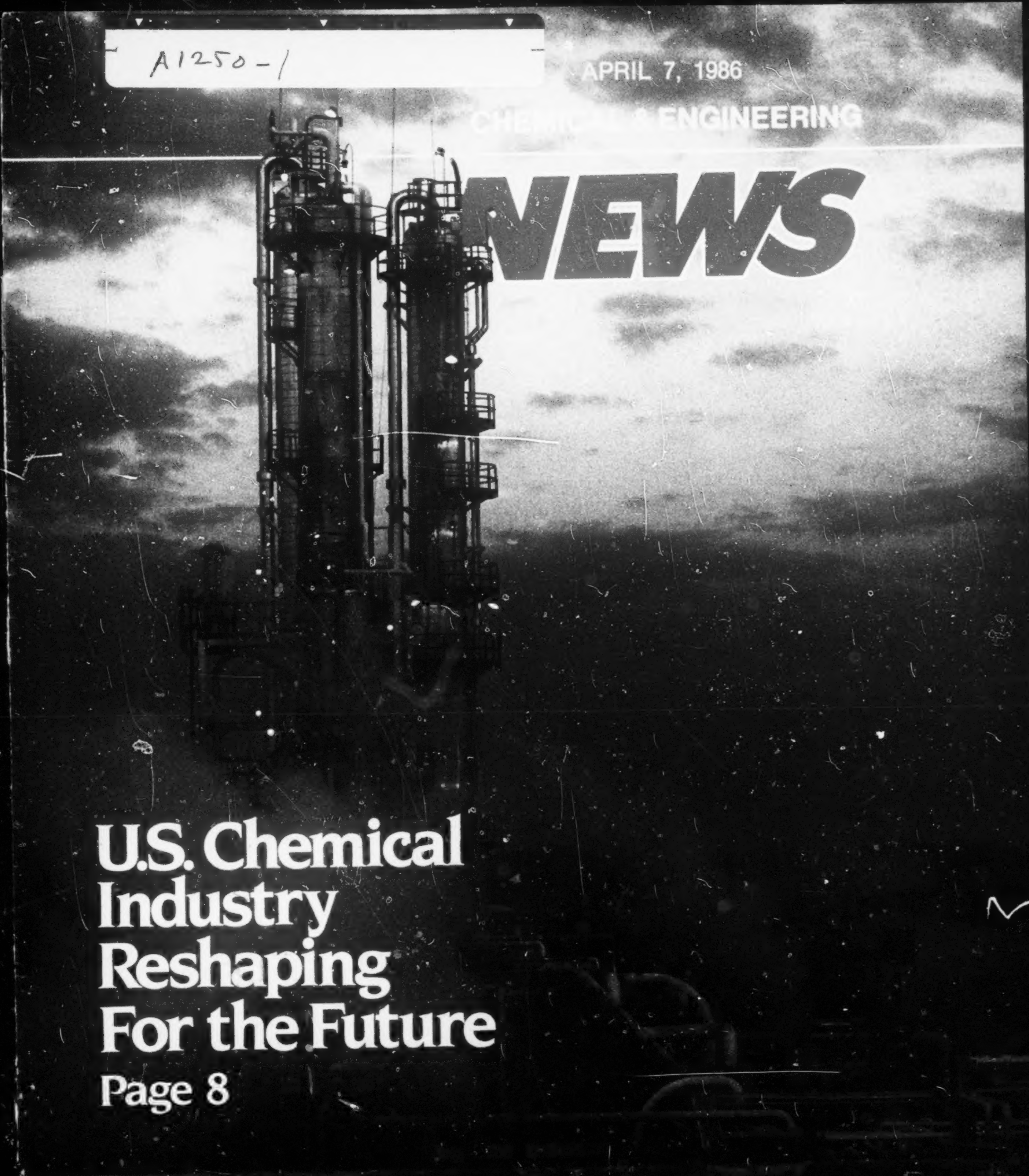
CHEMICAL & ENGINEERING NEWS



U.S. Chemical Industry Reshaping For the Future

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CHEMICAL & ENGINEERING
NEWS

Volume 64, Number 14
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APRIL 7, 1986

News of the Week

- **OSHA slaps $1.4 million fine on Union Carbide for alleged health and safety violations at its Institute, W.Va., plant.** Page 4
- **EPA asks Monsanto for more data before issuing an environmental use permit on its genetically engineered microbial pesticide.** Page 5
- **Denys Henderson will become the chairman of U.K.'s Imperial Chemical Industries in 1987.** Page 5
- **NSB committee finds serious deterioration of undergraduate education in science, mathematics, and engineering.** Page 6
- **Decline in crude oil prices gives organic chemicals producers temporary profit boost.** Page 6

Cover: Copolymer Rubber & Chemical Corp.'s
EPDM plant at Addis, La.
Photo by Steve Chenn

Government

National Academy of Engineering's choice of John Welch to head its council points up plan to lead U.S. technology policy. **Page 13**

Department of Defense report on Soviet military R&D describes it as huge and catching up with the West in some areas. **Page 14**

Science

Proliferation of software for IBM and compatible personal computers gives them wider use in chemistry labs and triggers the formation of a user group to provide a forum for exchange of ideas. **Page 17**

Technology

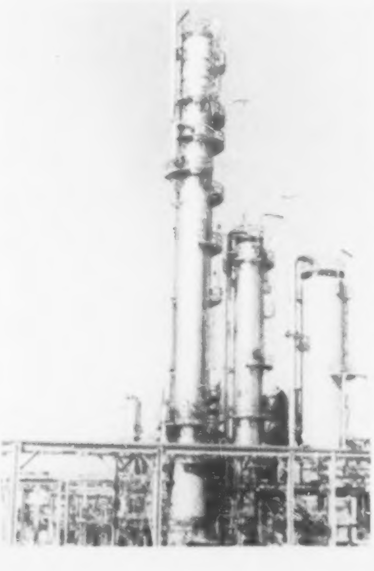
U.K. Atomic Energy Authority, with more control over management, financing of operations, hopes to boost contract R&D. **Page 19**

Books

"**An Environmental Agenda for the Future**" contains advice from experts; "Polycyclic Hydrocarbons and Carcinogenesis" assembles reports from leading researchers. **Page 20**

ACS News

Society honors its 50-year members; each receives a certificate, pin, and free registration at national and regional meetings. **Page 23**



Business

The U.S. chemical industry, in the midst of restructuring, is shifting from commodity chemicals to higher-value-added products, boosting productivity in attempt to remain viable. **Page 8**

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pires, he still will have three years to go before he reaches ICI's mandatory retirement age of 62. So it could be that he will hold the post of chairman for eight years instead of the usual five. ☐

Undergraduate science, math education scored

Undergraduate education in the U.S. in science, mathematics, and engineering is in serious trouble, according to a report from the National Science Board, the policymaking body of the National Science Foundation. Fixing it will require substantial increases in financial support primarily from "states, municipalities, and the host of supporters of private higher education." It also will require support from NSF at levels nearly as high as those the agency provided in the 1960s.

"The deterioration of collegiate science, mathematics, and engineering education is a grave, long-term threat to the nation's scientific and technical capacity, its industrial and economic competitiveness, and the strength of its national defense," the report says. It was prepared by NSB's Committee on Undergraduate Science & Engineering Education, chaired by Homer Neal, provost at the State University of New York, Stony Brook.

Three areas in particular require immediate attention "of the highest priority," the report notes. Those are laboratory instruction, faculty preparation, and course and curriculum development.

"Laboratory instruction, which is at the heart of science and engineering education, has deteriorated to the point where it is often uninspired, tedious, and dull," the report states. Faculty members are often unable to keep up to date in their discipline or work to improve their teaching skills. And courses and curricula "are frequently out-of-date in content, unimaginative, poorly organized for students with different interests, and fail to reflect recent advances in the understanding of teaching and learning."

NSF's role in tackling these problems should be to catalyze and stimulate efforts of others, the NSB committee says. It calls for establishing a permanent NSF presence in undergraduate mathematics, engineering, and the sciences "no later than 1989." NSF's own expenditures in this area need to be increased $100 million by 1990, according to the report, up from estimated expenditures of $13 million in the current year's budget and no program at all in the early 1980s.

The report acknowledges that it is not going to be easy to get an additional $100 million in NSF support for undergraduate support in the current federal budget climate. Nevertheless, it indicates NSF should go ahead with the recommended programs, even if it has to take the money from other programs to do so. Altogether, state governments, municipalities, industry, and other parts of the federal government will need to spend an extra $1 billion per year "to make an appropriate response to the national needs." ☐

Report urges $100 million rise for NSF undergraduate programs

$ Millions	1987	1988	1989
Laboratory development	—	$10	$ 20
Instrumentation	$ 2	12	32
Faculty enhancement	7	17	20
Course and curriculum	—	7	13
Comprehensive improvement			10
Undergraduate research	4	12	12
Minority institutions	—	5	5
Planning			1
TOTAL	$13	$63	$113

Note: Data are for fiscal years.

Declining oil prices boost chemical profits

Producers of most big-volume organic chemicals are reveling in improved profits as declining crude oil prices lower their feedstock costs faster than selling prices decline. The good feeling may not last, however, because selling prices are indeed falling and will catch up with declining feedstock prices in a relatively short time.

As a consequence of the oil price drop, the composition of feedstocks to steam crackers, which are sources for major-volume olefins and many aromatics, is being changed. Where possible, more heavy feedstocks obtained from crude oil—naphthas and gas oils—are used in place of light hydrocarbons such as ethane. Prices for ethane have declined less than prices for heavier materials, because natural gas prices haven't fallen so much as those for crude oil. For example, ethane's price at the beginning of April was about 16 cents per gal on the Gulf Coast, down roughly a third from its year-end price, whereas the crude oil price was down by half.

Uncertainties about future feedstock costs play havoc with selling price forecasts at this time. The risk of holding relatively high-priced materials makes inventories undesirable for both producers and consumers of chemicals. Spot buying for immediate consumption is increasing as a share of sales to producers of first- and second-level derivatives of olefins and aromatics.

Currently, inventories of ethylene are low and demand for ethylene continues strong owing to polymer demands. Operating steam crackers are being run at nearly 95% of nameplate capacity. This condition is causing ethylene prices to hold at about 16 cents per lb, although some sales involve determining actual April prices after the month is over. At 16 cents, ethylene prices are down less than 20% from January.

Pressure stays on prices of other olefins such as propylene and butadiene owing to production increases as steam cracker feedstocks shift more toward heavier materials. Propylene prices also are pressured by refinery-produced propylene, now much less in demand as an alkylation feedstock because of very low limits on use of lead alkyls in gasoline. As a result, polypropylene producers are getting better margins.

Larger amounts of benzene are being sold on a spot basis. Contract prices, typically 85 cents per gal, are tied in with large temporary voluntary allowances (discounts) used to bring contract prices closer to spot prices. ☐

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APRIL 21, 1986
CHEMICAL & ENGINEERING
NEWS

A1250-1

C&EN's Top 50 Chemical Products

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CHEMICAL & ENGINEERING NEWS

APRIL 21, 1986

News of the Week

- **More than 11,000 attended the ACS national meeting in New York City.** Page 4
- **Polymer implant allows insulin release to be varied in response to diabetic's need.** Page 5
- **Chemists and engineers must be more active in helping government shape science policy.** Page 5
- **Snapshots taken at ACS meeting in the Big Apple.** Page 6
- **Some first-quarter earnings results are hurt by the ailing agricultural economy.** Page 7
- **Congressman schedules hearings on controversial licensing of vaccine for pigs.** Page 7
- **Method of detecting AIDS virus in cells from infected individuals developed by Cetus Corp.** Page 8

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Business

Production of polymers continued to rise in 1985, despite a drop in synthetic rubber output and no growth in fibers. **Page 15**

International Business

Canadian chemical industry looks for a continued, although modest, recovery from the 1981–82 recession. **Page 17**

Government

Administration forms strategy to prevent abuses of U.S. patents and copyrights by foreign competitors. **Page 19**

Science

Scanning tunneling microscopy allows researchers to produce images of surfaces in which individual atoms are resolved. **Page 22**

Genes that specify red, blue, and green pigments responsible for color vision in humans isolated by Stanford scientists. **Page 25**

Priestley Medal Address

Priestley Medalist Karl Folkers discusses research results in use of vitamins B_6 and B_2, coenzyme Q_{10} to treat diseases. **Page 27**

ACS Annual Report

A record high membership, several new publications, and increased electronic services from CAS highlight ACS in 1985. **Page 31**

ACS News

Dale Baker, retiring as CAS director, has brought the processing and disseminating of chemical data into the computer age. **Page 60**

Cover Story

Production of chemicals in C&EN's Top 50 group dropped 2.6% last year from the 1984 level; slump in agricultural use was especially devastating to major inorganics. **Page 12**

Top 50 Chemicals Production Dropped Moderately in 1985

Inorganic chemicals output fell most sharply in overall decline; biggest single decrease last year was registered by methanol

David Webber, C&EN New York

Chiefly because of the continuing slump in the U.S. farm economy, production of many major inorganic chemicals declined sharply in 1985 from the year before. As a result, output of basic chemicals, as indicated by C&EN's Top 50 chemicals group, fell 2.6% last year from the 1984 level. The drop ended a string of two consecutive years during which Top 50 chemicals production had increased from the previous year.

The year was a poor one for inorganic chemicals nearly across the board. With substantial decreases in production of major fertilizer chemicals, including phosphoric acid, urea, and potash, as well as of other big-volume inorganics like chlorine and sodium hydroxide, composite output of the inorganic chemicals on the Top 50 list declined 3.9% last year from 1984. Over the past five years, inorganics production has fallen at an average annual rate of 1.6%.

Nor was 1985 a banner year for the organic chemicals component of the Top 50. Production of those substances was essentially level, registering a scant 0.1% increase over 1984's composite total. That reflection of mediocre demand left the 1985 output total just below its level in 1980, when organics production amounted to 176 million lb.

Last year's decline was widespread, with 31 of the Top 50 chemicals registering a decrease from 1984 production. By contrast, output of all but six members of the group rose in 1984 from 1983 levels. Production in 1984 was the highest since 1980, a good year in which total output was just 1.4% below the

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back for many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1985. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, production figures for earlier years that appear in the table on page 13 are different in some cases from those published in last year's Top 50 report. The final reports also can affect the rankings of chemicals. The 1984 rankings of 26 of the chemicals listed in the table, for example, are different from those in the similar table published by C&EN a year ago (C&EN, May 6, 1985, page 11).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead-burned) dolomite is excluded in the calculation of lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily, because they are considered to be products of oil companies and because they have many nonchemical uses.

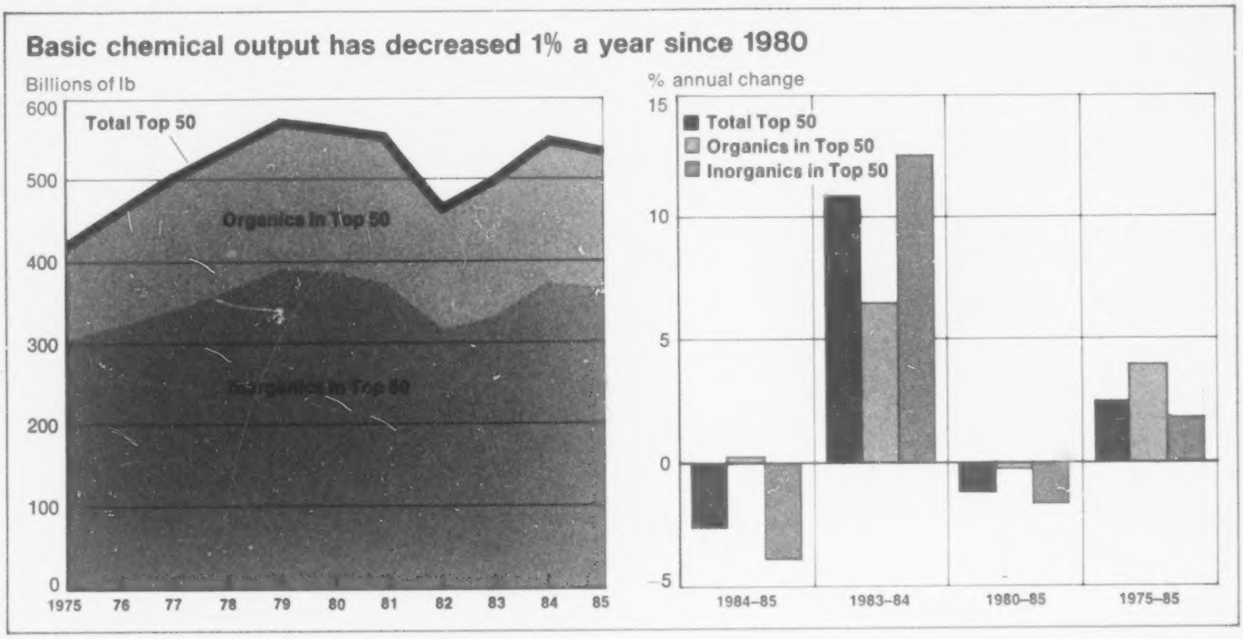
There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically.

Production figures are published by the government and trade associations in a variety of units—millions of pounds, thousands of tons, billions of cubic feet, millions of gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN not only gives production in common units but converts production to billions of pounds as well.

Top 50 chemicals output declined 3% last year

Rank			Billions of lb		Common units[b]		Average annual growth			
1985	1984[a]		1985	1984	1985	1984	1984–85	1983–84	1980–85	1975–85
1	1	**Sulfuric acid**	79.23	83.60	39,615 tt	41,802 tt	−5.2%	11.6%	−2.1%	2.0%
2	2	**Nitrogen**	46.88	47.90	647 bcf	661 bcf	−2.1	18.0	6.2	9.8
3	3	**Ammonia**	32.40	33.38	16,201 tt	16,692 tt	−2.9	19.6	−3.8	−0.1
4	4	**Lime[c]**	31.60	31.98	15,800 tt	15,992 tt	−1.2	7.6	−3.6	−1.4
5	5	**Oxygen**	31.37	31.87	379 bcf	385 bcf	−1.6	11.3	−2.5	0.7
6	6	**Ethylene**	30.55	31.38	30,550 mp	31,383 mp	−2.7	9.4	1.3	4.1
7	7	**Phosphoric acid**	20.98	22.74	10,492 tt	11,370 tt	−7.7	16.4	−0.7	3.2
8	8	**Sodium hydroxide**	20.35	21.83	10,175 tt	10,914 tt	−6.8	6.7	−2.6	0.5
9	9	**Chlorine**	19.09	21.40	9,545 tt	10,699 tt	−10.8	7.4	−3.5	0.4
10	10	**Sodium carbonate[d]**	17.10	17.02	8,551 tt	8,511 tt	0.5	0.5	0.7	7.0
11	12	**Nitric acid**	15.56	15.45	7,778 tt	7,726 tt	0.7	10.9	−3.4	0.3
12	11	**Propylene**	14.93	15.56	14,930 mp	15,559 mp	−4.0	11.5	1.8	5.5
13	14	**Ammonium nitrate[e]**	13.81	14.29	6,906 tt	7,146 tt	−3.4	14.5	−5.4	−0.3
14	15	**Ethylene dichloride**	13.63	10.71	13,632 mp	10,710 mp	27.3	−6.9	4.2	5.5
15	13	**Urea[f]**	13.11	14.87	6,556 tt	7,433 tt	−11.8	23.6	−3.5	6.3
16	16	**Benzene**	9.73	9.71	1,321 mg	1,318 mg	0.2	6.9	−8.0	2.6
17	17	**Carbon dioxide[g]**	8.63	9.13	4,315 tt	4,565 tt	−5.5	16.5	7.5	8.8
18	20	**Ethylbenzene**	8.55	7.56	8,547 mp	7,562 mp	13.0	−4.0	2.3	5.9
19	22	**Vinyl chloride**	7.78	6.09	7,775 mp	6,085 mp	27.8	−11.5	3.8	6.4
20	19	**Styrene**	7.45	7.71	7,454 mp	7,709 mp	−3.3	13.3	1.7	4.8
21	23	**Terephthalic acid[h]**	7.17	5.91	7,165 mp	5,912 mp	21.2	5.1	3.4	4.5
22	18	**Methanol**	5.98	8.19	5,979 mp	8,186 mp	−27.0	2.6	−3.5	1.5
23	25	**Ethylene oxide**	5.83	5.70	5,833 mp	5,699 mp	2.4	3.0	2.2	2.7
24	24	**Formaldehyde[i]**	5.70	5.82	5,699 mp	5,815 mp	−2.0	6.4	0.5	2.3
25	26	**Hydrochloric acid**	5.56	5.46	2,780 tt	2,732 tt	1.8	12.9	−0.8	3.3
26	21	**Xylene**	5.25	6.15	729 mg	854 mg	−14.6	17.6	−4.3	1.3
27	27	**Toluene[j]**	4.99	5.28	688 mg	728 mg	−5.5	−6.7	−7.5	−0.2
28	29	***p*-Xylene**	4.72	4.26	4,724 mp	4,264 mp	10.8	3.6	2.2	6.6
29	28	**Ethylene glycol**	4.68	4.82	4,679 mp	4,823 mp	−3.0	9.0	1.3	2.1
30	30	**Ammonium sulfate**	4.10	4.13	2,049 tt	2,067 tt	−0.9	5.7	−0.8	−0.3
31	31	**Cumene**	3.33	3.75	3,328 mp	3,754 mp	−11.3	12.2	−0.8	5.2
32	32	**Potash[k]**	2.92	3.45	1,325 tmt	1,564 tmt	−15.3	9.4	−10.0	−5.2
33	35	**Acetic acid**	2.88	2.62	2,875 mp	2,619 mp	9.8	−6.7	−0.7	2.7
34	34	**Phenol[l]**	2.78	2.89	2,777 mp	2,889 mp	−3.9	9.6	1.6	4.7
35	33	**Carbon black**	2.57	2.89	2,571 mp	2,893 mp	−11.1	15.9	0.2	−0.7
36	36	**Butadiene[m]**	2.53	2.45	2,525 mp	2,452 mp	3.0	4.2	−2.0	−0.3
37	44	**Sodium sulfate[n]**	2.40	1.74	1,199 tt	872 tt	37.5	2.1	1.0	−0.2
38	38	**Acrylonitrile**	2.35	2.22	2,346 mp	2,219 mp	5.7	3.4	5.1	6.8
39	40	**Vinyl acetate**	2.11	2.02	2,112 mp	2,024 mp	4.3	3.1	1.9	5.1
40	37	**Aluminum sulfate**	2.01	2.26	1,003 tt	1,129 tt	−11.2	2.4	−4.8	−1.3
41	43	**Propylene oxide**	1.88	1.78	1,882 mp	1,779 mp	5.8	−4.5	1.3	2.1
42	42	**Acetone**	1.80	1.86	1,801 mp	1,862 mp	−3.3	0.2	−2.8	0.9
43	41	**Cyclohexane**	1.74	1.99	1,743 mp	1,994 mp	−12.6	20.4	−2.4	0.1
44	49	**Methyl *tert*-butyl ether[o]**	1.69	1.38	1,693 mp	1,376 mp	23.0	64.0	nm	nm
45	45	**Titanium dioxide**	1.63	1.67	814 tt	835 tt	−2.5	10.3	2.6	3.0
46	39	**Calcium chloride[p]**	1.60	2.10	800 tt	1,049 tt	−23.7	22.4	−4.0	−3.7
47	46	**Sodium silicate**	1.47	1.50	736 tt	750 tt	−1.9	3.0	−1.8	0.2
48	48	**Adipic acid**	1.30	1.39	1,298 mp	1,390 mp	−6.6	8.6	−2.5	−0.3
49	50	**Sodium tripolyphosphate**	1.21	1.35	607 tt	675 tt	−10.1	0.9	−3.5	−2.4
50	47	**Isopropyl alcohol**	1.12	1.39	1,118 mp	1,394 mp	−19.8	15.3	−9.4	−3.0
TOTAL ORGANICS			175.55	175.46			0.1%	6.5%	−0.1%	4.0%
TOTAL INORGANICS			362.48	377.16			−3.9%	12.5%	−1.6%	1.8%
GRAND TOTAL			538.03	552.62			−2.6%	10.8%	−1.1%	2.4%

a Revised. **b** tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. **c** Except refractory dolomite. **d** Natural and synthetic. **e** Original solution. **f** 100% basis. **g** Liquid and solid only. **h** Includes both acid and ester without double counting. **i** 37% by weight. **j** All grades. **k** K_2O basis. **l** Synthetic only. **m** Rubber grade. **n** High and low purity. **o** Production data for earlier years unavailable. **p** Solid and liquid. nm = not meaningful.



Basic chemical output has decreased 1% a year since 1980

industry's historical high reached in 1979. In 1985, by comparison, composite production was 6.6% below the 1979 peak.

For the entire Top 50 group, composite output dwindled at a 1.1% compound annual rate between 1980 and 1985. Over the past 10 years, on the other hand, Top 50 production grew at an average annual rate of 2.4%. Between 1974 and 1984, Top 50 output grew at an annual rate of just 1.4%. That figure is really a better indicator of the chemical industry's long-term growth rate, however, since 1985's 10-year growth rate is calculated on a base of output in 1975, a deep recession year. A clearer picture of the industry's essential maturity emerges in a calculation of production growth between 1976 and 1985: an average annual rate of just 1.6%.

The greatest individual growth in terms of production last year all came on the side of the organics. The largest increase in 1985 was registered by vinyl chloride, output of which rose 28% to 7.8 billion lb. The gain pushed the chemical up to 19th place on the Top 50 list from 22nd place in 1984. Next, in terms of percentage gains, came ethylene dichloride, up 27% to 13.6 billion lb; methyl *tert*-butyl ether (MTBE), slowing from its 1984 increase of 64%, but still up 23% last year to 1.7 billion lb; terephthalic acid, up 21% to 7.2 billion lb; and ethylbenzene, up 13% to 8.6 billion lb.

On the negative side, the biggest decrease in production last year was recorded by methanol. Output of methanol dropped 27% to 6 billion lb, a decline that demoted the chemical from 18th on the 1984 list to 22nd in 1985. The other products leading the list of production decreases last year were calcium chloride, down 24% to 1.6 billion lb; isopropyl alcohol, down 20% to 1.1 billion lb; potash, down 15% to 2.9 billion lb; and xylene, down 15% to 5.3 billion lb. Output of many other products also fell more than 10% last year, including chlorine, urea, cumene, carbon black, aluminum sulfate, cyclohexane, and sodium tripolyphosphate.

The production decline for calcium chloride is probably overstated in this list because of improvements in government output statistics. Before 1985, the Bureau of Mines, which tracks calcium chloride production, had to estimate output of a major producer that refused to supply any data. Last year, that company for the first time provided what it termed a good approximation of its production. The Bureau of Mines therefore considers its 1985 statistic more or less a "hard number," but now figures that previous years' statistics are probably on the high side. No revision is planned.

Between 1980 and 1985, the overall downward trend was defied by 21 of the chemicals on the Top 50 list. Leading in individual growth over the five-year span were industrial gases. Output of carbon dioxide grew at an annual compound rate of 7.5%, and production of nitrogen rose at an average annual rate of 6.2%. Following on the five-year growth list were acrylonitrile, up an average 5.1% a year; ethylene dichloride, up an average 4.2% a year; and vinyl chloride, up an average 3.8% a year.

Leading the general decline between 1980 and 1985 was potash, down a remarkable 10% a year on a compounded basis. The other products with the greatest individual decreases in production were isopropyl alcohol, down 9.4% a year on average; benzene, down 8% a year on average; toluene, down 7.5% a year on average; and ammonium nitrate, down 5.4% a year on average.

Over the past 10 years, all but 14 chemicals on the Top 50 list have increased in output. Again, the best performers were the industrial gases nitrogen and carbon dioxide. Production of nitrogen grew at an average annual rate of 9.8% over the decade, followed by carbon dioxide, output of which increased at an average annual rate of 8.8% during the period. Production of sodium carbonate grew at an average annual pace of 7%, and output rose 6.8% a year on average for acrylonitrile and 6.6% a year on average for *p*-xylene.

The greatest average annual rate of decline in production over the past 10 years was registered by potash. Output has fallen at a compound rate of 5.2% a year. Other shrinking products were calcium chloride, down 3.7% a year on average; isopropyl alcohol, down 3% a year on average; and sodium tripolyphosphate, down 2.4% a year on average.

The fastest growing chemical in recent years has been MTBE, which has increased rapidly in output as production facilities have come on stream. It is impossible to calculate the gasoline additive's long-term growth rates, however, because output of the chemical was too small five years ago to merit an individual line entry in the International Trade Commission's annual compendium of synthetic organic chemicals production.

As has generally been the case, the group comprising the 10 largest chemical commodities in terms of production remained the same in 1985 as the year before. There was a good deal of rank shifting throughout the rest of the list, however. In all, 30 of the chemicals on the list either moved up or down in ranking.

Besides the rise already noted for vinyl chloride and the fall noted for methanol, other significant changes in rank included xylene, which, with its 15% drop in output, fell to 26th place from 21st in 1984; MTBE, which jumped to 44th place from 49th in 1984; and calcium chloride, which plunged to 46th place from 39th in 1984 (previous years' production, however, may have been overstated, as noted). ☐

Polymer production set record last year

Despite a sharp drop in synthetic rubber output, overall polymer production continued to rise in 1985. Output of plastics, synthetic fibers, and synthetic rubber, which had notched a record high in 1984, rose to a new peak of 49.5 billion lb last year. The growth, which marked the third consecutive annual increase for the product group, lifted the output total 2.2% above the 1984 record and 6.5% above the earlier peak of 46.5 billion lb reached in 1979.

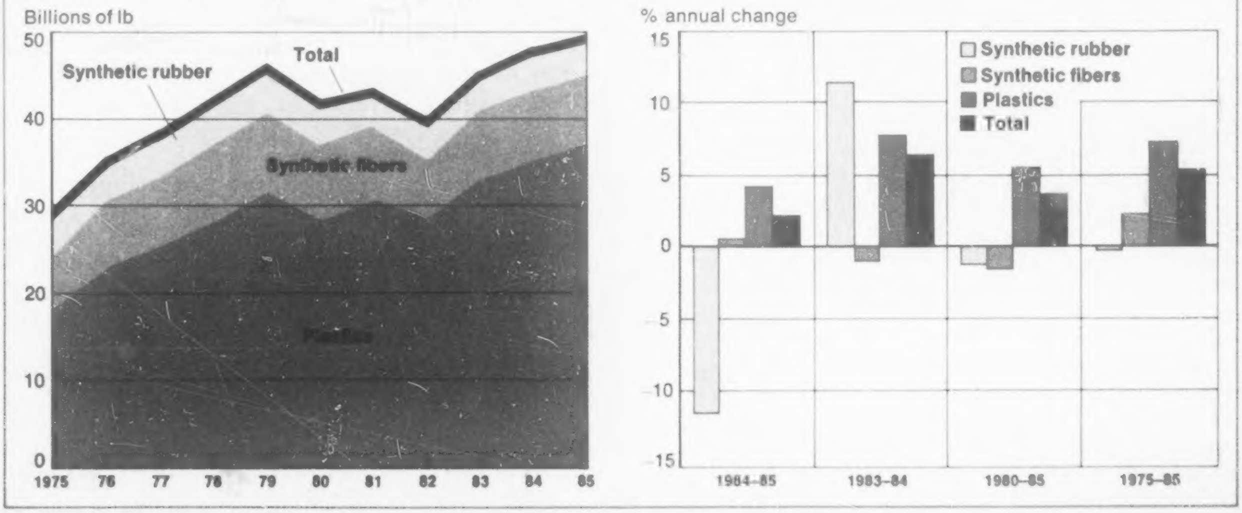
Leading the way was the plastics segment, which grew 4.4% last year and accounted for three quarters of the entire polymers group's production total. The strongest growth was registered by the thermoplastics side of the segment, highlighted by a 9.6% increase in high-density polyethylene output and increases of 5.7% and 5.6%, respectively, for low-density polyethylene and polystyrene. Overall, thermoplastics production rose 5% last year.

By comparison, output of thermosetting resins grew just 1.5% in 1985, despite a strong 4.8% rise in production of phenolic resins. The problem was weak performance by other members of the group: melamine resins, down 8.6%; unmodified epoxy resins, down 5.2%; and unsaturated polyester resins, down 0.7%.

Over the past five years, by contrast, the thermosets led in production growth with an average annual gain of 6.6% compared with 5.3% for the thermoplastics. The chief reason was phenolic resins, output of which grew at a compound rate of 12% between 1980 and 1985. Other notable growth among plastics over the five-year span includes high-density polyethylene, up 8.7% a year on average, and polypropylene, up 7.1% a year on average.

Surveying 10-year production growth, almost all the plastics statistics for 1985 look good when compared with those for 1975, a year of sharp recession for the resins group.

Output was up for plastics, flat for fibers, and down for rubber in 1985



Total polymers production was just under 50 billion lb last year

	Billions of lb		Common units					Average annual growth			
	1985	1984	1985	1984	1983	1980	1975	1984–85	1983–84	1980–85	1975–85
PLASTICS (millions of lb)											
Thermosetting resins	**5.63**	**5.55**	**5,631**	**5,549**	**5,254**	**4,093**	**2,888**	**1.5%**	**5.6%**	**6.6%**	**6.9%**
Phenol, other tar acid resins	2.62	2.50	2,621	2,502	2,484	1,499	1,051	4.8	0.7	11.8	9.6
Urea resins	1.21	1.20	1,210	1,199	1,172	1,165	690	0.9	2.3	0.8	5.8
Polyesters (unsaturated)	1.22	1.23	1,223	1,232	1,084	947	834	−0.7	13.7	5.2	3.9
Epoxies (unmodified)	0.39	0.41	385	406	334	315	198	−5.2	21.6	4.1	6.9
Melamine resins	0.19	0.21	192	210	180	167	115	−8.6	16.7	2.8	5.3
Thermoplastic resins	**31.53**	**30.04**	**31,525**	**30,036**	**27,799**	**24,335**	**15,423**	**5.0%**	**8.0%**	**5.3%**	**7.4%**
Low-density polyethylene	8.89	8.41	8,889	8,413	8,041	7,291	4,743	5.7	4.6	4.0	6.5
PVC and copolymers	6.77	6.76	6,772	6,760	6,066	5,470	3,648	0.2	11.4	4.4	6.4
High-density polyethylene	6.67	6.09	6,671	6,085	5,691	4,405	2,468	9.6	6.9	8.7	10.5
Polystyrene[a]	4.05	3.84	4,054	3,838	3,567	3,521	2,662	5.6	7.6	2.9	4.3
Polypropylene	5.14	4.94	5,139	4,940	4,434	3,648	1,902	4.0	11.4	7.1	10.5
TOTAL[b]	**37.16**	**35.59**	**37,156**	**35,585**	**33,053**	**28,428**	**18,311**	**4.4%**	**7.7%**	**5.5%**	**7.3%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.60**	**0.63**	**595**	**629**	**640**	**806**	**749**	**−5.4%**	**−1.7%**	**−5.9%**	**−2.3%**
Rayon	0.39	0.43	390	430	411	490	436	−9.3	4.6	−4.5	−1.1
Acetate[c]	0.21	0.20	205	199	229	316	313	3.0	−13.1	−8.3	−4.1
Noncellulosics[d]	**7.55**	**7.47**	**7,549**	**7,473**	**7,534**	**7,874**	**5,874**	**1.0%**	**−0.8%**	**−0.8%**	**2.5%**
Polyester	3.34	3.39	3,341	3,392	3,543	3,989	2,995	−1.5	−4.3	−3.5	1.1
Nylon[e]	2.34	2.41	2,343	2,412	2,418	2,358	1,857	−2.9	−0.2	−0.1	2.4
Glass fiber	na	1.39	na	1,394	1,167	867	547	na	19.5	na	na
Olefin	1.23	1.00	1,234	998	902	748	497	23.6	10.6	10.5	9.5
Acrylic[f]	0.63	0.67	631	671	671	779	525	−6.0	0.0	−4.1	1.9
TOTAL[b,d]	**8.14**	**8.10**	**8,144**	**8,102**	**8,174**	**8,680**	**6,623**	**0.5%**	**−0.9%**	**−1.3%**	**2.1%**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[g]	1.78	2.11	805	958	904	1,074	1,179	−16.0%	6.0%	−5.6%	−3.7%
Polybutadiene	0.73	0.79	329	359	333	311	290	−8.4	7.8	1.1	1.3
Ethylene-propylene	0.47	0.47	215	215	175	144	84	0.0	22.9	8.3	9.9
Nitrile	0.12	0.15	55	67	55	63	55	−17.9	21.8	−2.7	0.0
Other[h]	1.11	1.23	503	556	468	423	332	−9.5	18.8	3.5	4.2
TOTAL[b]	**4.20**	**4.75**	**1,907**	**2,155**	**1,935**	**2,015**	**1,940**	**−11.5%**	**11.4%**	**−1.1%**	**−0.2%**

a No longer includes acrylonitrile-butadiene-styrene or styrene-acrylonitrile resins; historical data are restated. **b** Totals are for those products listed. Totals may not add because of rounding. **c** Includes diacetate and triacetate yarn; does not include cigarette filters. **d** All totals and growth statistics restated to exclude glass fiber. **e** Includes aramid. **f** Includes modacrylic. **g** Excludes high-styrene latex. **h** Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl, polyisoprene, chlorosulfonated polyethylene, polyisobutylene, and acrylo, fluoro, polysulfide, and silicone elastomers. **na** = not available. **Sources:** Society for the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

Between 1975 and 1985, production for the entire plastics segment rose at a compound rate of 7.3%. When compared with postrecession 1976, on the other hand, average annual growth for the entire group through 1985 was a more modest but still strong 5.5%.

Inundated by the tide of imports that has hit much of the textile sector the past few years, the synthetic fibers segment still managed an 0.5% increase in composite production in 1985 compared with the year before. The noncellulosics group, which accounted for more than 90% of fiber production last year, recorded a 1% output increase; cellulosic production fell 5.4%. Actually, production of almost all fibers declined last year. The only reason the composite total rose was because of a 24% increase in output of olefin fibers.

Over the past five years, fibers output has declined at a compound rate of 1.3% a year, mainly because of an average annual 3.5% drop in output of polyester fibers. Polyester fibers accounted for 41% of all synthetic fibers production in 1985.

The overall growth rate and other totals also exclude production of glass fiber, which was not reported for 1985 by the Textile Economics Bureau. Total shipments of glass fiber last year, including both domestic shipments and exports, were 1.26 billion lb, down about 4% from the year before.

A nearly across-the-board negative performance brought synthetic rubber production down 12% in 1985 compared with the previous year. Only ethylene-propylene rubber, output of which was absolutely flat, escaped the minus column. The worst declines were turned in by nitrile rubber, down 18%, and styrene-butadiene rubber, which accounted for more than 40% of all synthetic rubber production, down 16%.

Synthetic rubber continues to be the sick man of the polymers group. Over the past five years, the segment's production has declined at an average annual rate of 1.1%. In the past 10 years, the compound rate of decline has been 0.2%. The chief reason is the steady decrease of styrene-butadiene rubber output, down at a compound rate of 5.6% between 1980 and 1985 and down at a compound rate of 3.7% between 1975 and 1985. □

Canadian Chemical Upturn Continues

Despite some troubling signs on the economic horizon, the Canadian chemical industry is moving into the second quarter of the year with a fair degree of confidence.

The new federal budget will take a bigger tax bite out of corporate earnings. Plunging oil prices will take a heavy toll in some provinces, particularly energy-rich Alberta. A weak Canadian dollar and relatively high interest rates still worry some Canadian economists.

But the general consensus is that, with interest rates starting to ease, the Canadian economy will be able to overcome its other handicaps and chalk up its fourth successive year of recovery following the 1981–82 recession. Growth certainly won't keep pace with the 4.5 to 5% gross national product increases recorded over the past two years. But, at an expected 3 to 3.5%, it likely will give the chemical industry an opportunity to continue its production and sales gains.

Average operating rates of Canadian chemical plants are up. The capacity utilization rate recorded by Statistics Canada jumped 4% last year and has been increasing steadily each quarter. Operating rates for industrial chemicals, which include the major petrochemicals, were up 7% last year. Other chemical industry segments with strong gains include paints and varnishes, plastics fabrication, rubber and plastics products, and pharmaceuticals.

There were—and still are—some weak spots. Production of the important fertilizer and pulp and paper chemicals grew very little, remained level, or were down last year. Output of sulfuric acid, for instance, was down 3.8% in 1985. Phosphoric acid, ammonium phosphate, and hydrochloric acid production also was off.

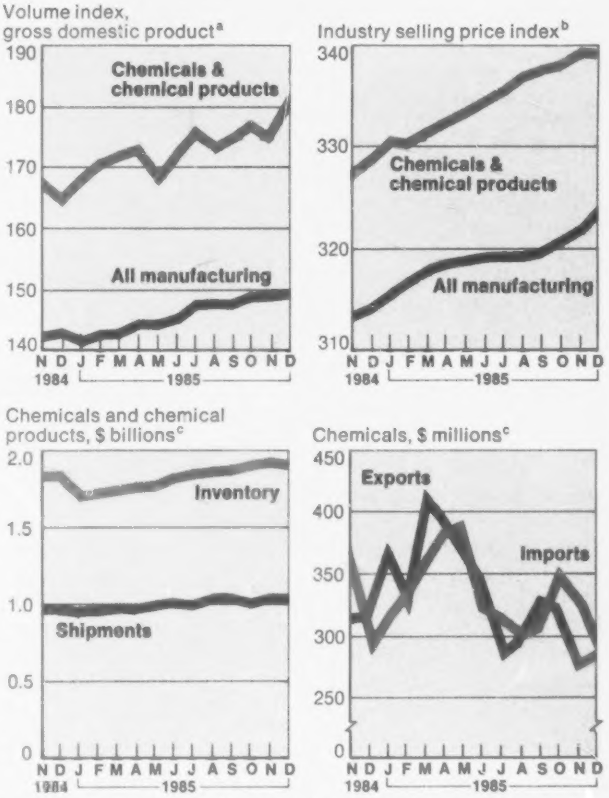
Canadian ammonia production increased 3.6% last year to 3.6 million metric tons. But, because of excess supplies and low prices, some companies with new ammonia projects in the works are taking a hard, second look at them. Five new ammonia plants are due on stream in Canada over the next two years. Two of the projects, however, already have been delayed.

On the other hand, output of ethylene and some of its key derivatives soared. Ethylene output rose 19%, and low-density polyethylene jumped a heady 39%. Polyvinyl chloride was another winner with an estimated 11% advance in production.

Higher exports, particularly to the U.S., can take a lot of the credit for the strong performance of plastics and resins. Despite the weaker U.S. dollar, the Canadian dollar remains weak by comparison. This makes Canadian exports very competitive in U.S. markets.

If the early-bird, first-quarter report of Celanese Canada is any indication, the Canadian chemical industry will like 1986. Company sales during the quarter increased 8.7%. Profits, however, skyrocketed 233%.

Earl Anderson, New York



a Seasonally adjusted, 1971 = 100. b 1971 = 100. c For 1984, \$1.00 = \$1.31 Canadian; for 1985, \$1.00 = \$1.36 Canadian. **Source:** Statistics Canada

Ethylene and derivatives lead the way

Production, thousands of metric tons	1983	1984	1985	% change 1984–85
ORGANICS				
Ethylene	1196	1464	1744	19.1%
Propylene	715	656	648	−1.3
Benzene	580	549	688	25.4
Toluene	411	395	473	19.5
Xylene	426	406	415	2.3
PLASTICS				
Polyethylene, low density	412	529	733	38.7
Polyethylene, high density	211	227	229	1.1
Polyvinyl chloride	243	252	280[b]	11.1[b]
INORGANICS				
Hydrochloric acid	170	161	158	−2.3
Nitric acid	1061	1100	1128	2.5
Phosphoric acid[a]	656	691	627	−9.2
Sulfuric acid	3686	4043	3890	−3.8
Ammonia, anhydrous	2888	3493	3620	3.6
Ammonium phosphate	1259	1383	1301	−5.9
Chlorine	1385	1424	1424	0.0
Sodium hydroxide	1528	1574	1589	0.9

a 100% P_2O_5. b C&EN estimate. **Source:** Statistics Canada

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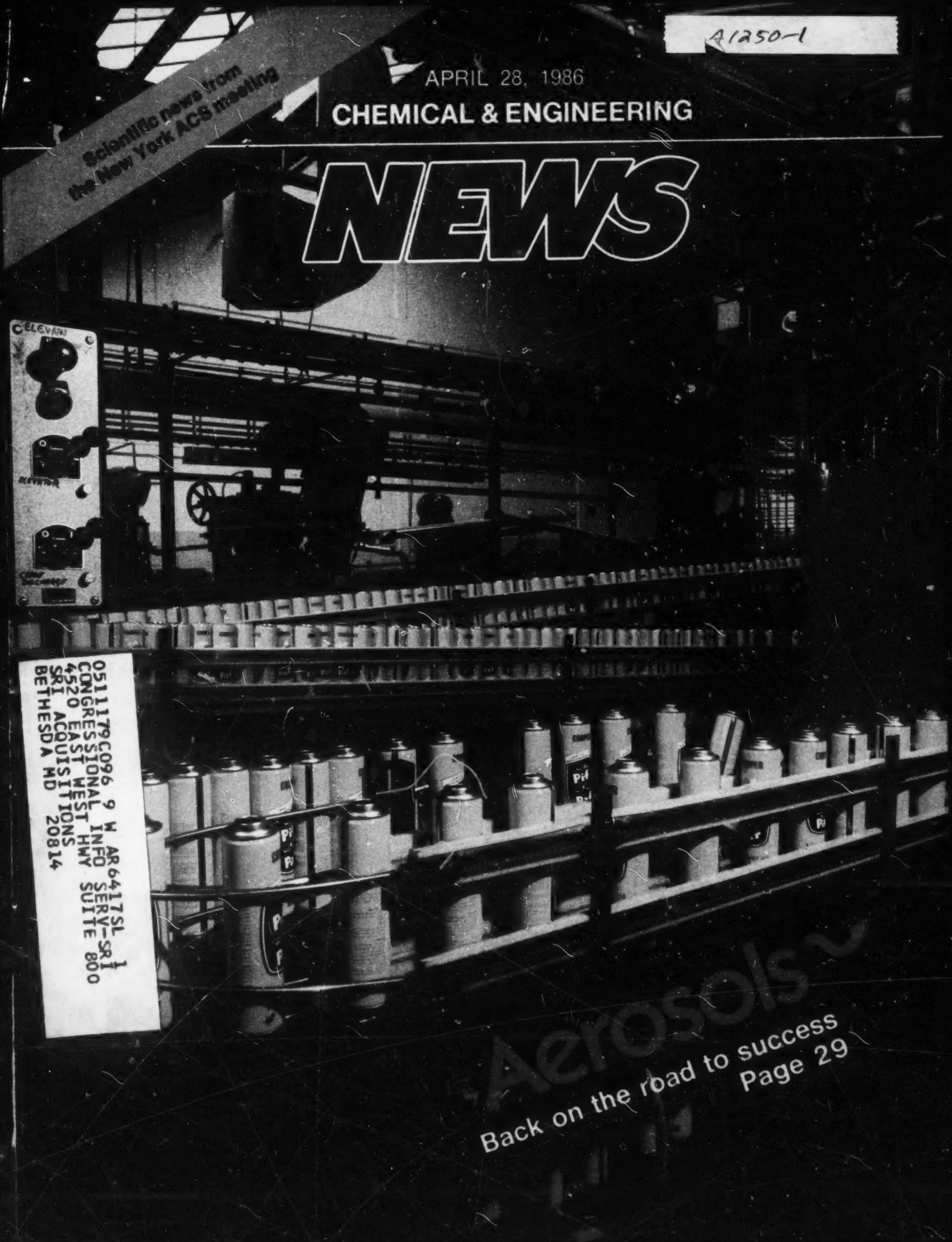
APRIL 28, 1986

CHEMICAL & ENGINEERING NEWS

Scientific news from the New York ACS meeting



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Aerosols~

Back on the road to success
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CHEMICAL & ENGINEERING
NEWS
APRIL 28, 1986

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News of the Week

- **First-quarter earnings indicate that personnel cutbacks and selling off of unprofitable businesses are now boosting profits.** **Page 4**
- **Union Carbide will sell its home and automotive products business to First Boston Inc.** **Page 5**
- **Long-term exposure to TCDD may lead to depression of parts of the immune system.** **Page 5**
- **EC Commission fines 15 makers of polypropylene for price fixing, market-sharing cartel.** **Page 6**
- **European Vinyl Corp. formed by Enichem and ICI to make vinyl and polyvinyl chloride.** **Page 6**

Cover: Aerosol cans of Wellcome Foundation's insecticide being produced at Metal Box plant in Sutton-in-Ashfield, England

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News Focus

Chemical community leaders discuss changes in industry, R&D, and education at both ACS and AIChE meetings. **Page 7**

Business

Output of sulfuric and phosphoric acids will be down about 5% this year because of global decline in fertilizer demand; polyethylene supply and demand will stay in balance during 1980s; amorphous polypropylene outlook seems bright. **Page 12**

Government

EPA plans national survey of homes to determine average levels of radon gas and pinpoint areas with especially high levels. **Page 19**

Technology

From the New York ACS meeting: hard times for coal liquefaction R&D; computer interpretation of analytical data; toxic effects of liquids from coal and oil shale; from AIChE meeting, stories on future of the petrochemical industry and CO_2 for enhanced oil recovery. **Page 22**

Science

From the New York meeting: thyroid disorders and resorcinol; programs for mainframe computers adapted to microcomputer. **Page 66**

ACS News

ACS national meeting in New York—in pictures; U.S. chemists are mostly male, white, and work in industry, survey shows. **Page 70**

Product Report

After a setback by the ban on chlorofluorocarbons, the aerosol industry is on the upswing again, especially in the U.K., Western Europe. **Page 29**

Major Mineral Acids Face Declining Demand

Production of sulfuric and phosphoric acids will drop this year because of lower global consumption of U.S. phosphate fertilizers

Bruce F. Greek, C&EN Houston

Domestic and export demand for phosphate fertilizers in 1986 will be weak, bringing a decline to production of sulfuric and phosphoric acids, the two largest-volume mineral acids. Output of the two acids will be down about 5%, dragging down with it plant operating rates. Major producers and users of those acids, mostly in the fertilizer industry, are debating whether a reversal of the declines will occur next year or later in the 1980s.

Even if output of the acids falls after 1986, plant operating rates might increase. A large amount of capacity to make either sulfuric or phosphoric acids is not operating and might be scrapped later. How much will be scrapped is uncertain. Undoubtedly, economics will be the key to operating old, inefficient plants in competition with new plants.

Moreover, operable capacity to make sulfuric acid from smelters (considered to be a by-product) and from direct manufacture seems to be threatened by the excess capacity and resulting weak prices. More than 5 million tons of 100% H_2SO_4 capacity is available at smelters even after the large amounts of capacity scrapped earlier in this decade. How much of the smelter capacity will be operating by 1990 is uncertain, but industry sources speculate that half of it will be shut down permanently.

Key Chemicals

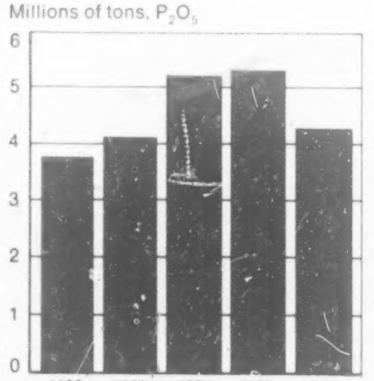
A similar, but smaller, overcapacity exists for phosphoric acid. Changes in the overcapacity and operating ratio of plants, however, have been, and are likely to be, more radical than those for sulfuric acid capacity. The situation stems partially from the necessary differences in operating conditions between the two kinds of plants. But a more important factor is the volatility of markets. For example, weather this spring in the major Midwest farming states has been poor, slowing the start of the growing season and reducing the time for application (and hence the quantity) of fertilizer to be used before planting.

Producers of phosphate fertilizers are hoping for a good fall season as well as improved exports of product later this year to help the start of the 1986–87 fertilizer year. They now are not expected to build much inventory to meet that demand. More inventory will be needed, however, by early 1987 to meet an expected improved demand.

Erratic export demand for phosphate fertilizers adds to the volatility of phosphoric acid plant operations. Exports were strong in the first nine months of 1985, but excessive inventories built up in buying countries, which reduced export demand late in the year. Slow exports of phosphates continued through early 1986, ending plans for increased production during the first half of the year. If a good U.S. fall fertilization season occurs, and if export demand rises strongly during the second half of 1986, inventories will be greatly reduced. Thus it's possible that the phosphate fertilizer industry and phosphoric and sulfuric acid producers could have a better business year in 1987 than they expect to have in 1986.

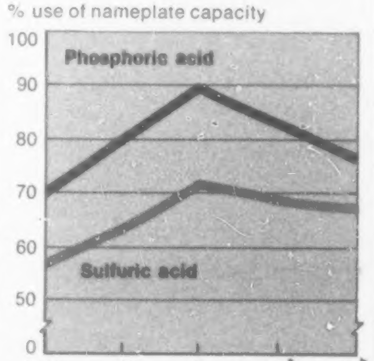
For details of the near-term outlook for sulfuric and phosphoric acids, please see the following pages.

Phosphate exports will fall this year



Source: C&EN estimates

Capacity use slips for major mineral acids



a Preliminary. b Estimated. **Sources:** U.S. Department of Commerce, C&EN estimates

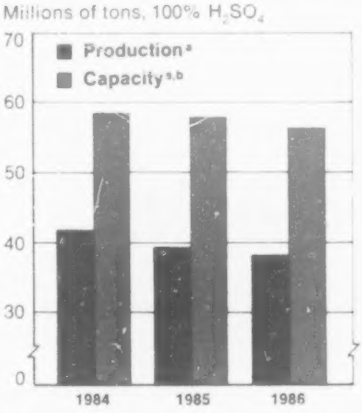
Key Chemicals

H_2SO_4

Sulfuric acid

- ***Production to decline***
- ***Capacity down more***
- ***Prices low and holding***

PRODUCTION/CAPACITY



a From all sources. b First quarter

MAJOR PRODUCERS

Allied-Signal, American Cyanamid, C-I-L, Du Pont, Stauffer Chemical (Chesebrough-Pond's)

HOW MADE

Sulfur dioxide obtained by burning sulfur or recovered from smelting is oxidized, reacted with water

MAJOR DERIVATIVES

None more than 5% of production

MAJOR END USES

Phosphate and other fertilizer manufacturing 70%, metals production and processing 10%

FOREIGN TRADE

Exports—holding at about 150,000 tons per year, imports—holding at about 500,000 tons per year

PRICES

List for smelter acid, \$20 to \$50 per ton; for virgin acid, \$55 to \$95 per ton

Production of sulfuric acid in 1986 will be down again because of a sizable decline in exports of diammonium phosphate (DAP) and lower U.S. farm consumption of phosphate fertilizers—both of which depend on sulfuric acid in their manufacture. Output of the acid will drop 3.5% from last year, following a decline of more than 5% in 1985. Total capacity to make sulfuric acid also declined last year as a result of acid plant closures at several copper ore smelters and at other sites.

In 1986, output of sulfuric acid on a 100% H_2SO_4 basis will total about 38.2 million tons, down from the preliminary estimate of 39.6 million tons in 1985 and down from 41.8 million tons in 1984. Production of the acid peaked in 1980 at nearly 44 million tons.

Capacity dropped relatively steeply in 1985, with an estimated net decline of 1.5 million tons, three times the drop in 1984. Not all of the remaining 56 million tons of capacity is operating. Some plants may never operate again.

Estimates of 1986 output are based on some assumptions that could prove to be incorrect. One assumption is that U.S. use of phosphate fertilizers this spring will come within 95% of use last spring, despite large acreages of farmland left unplanted. Another is that the fall application will be better than it has been in the past two fall seasons, when use of phosphate fertilizers declined about 20% each season.

Outside the fertilizer industry, sulfuric acid demand will be essentially the same as last year. The metals processing industries (such as steel making) likely will hold present levels of production. Chemicals, paper and pulp, and petroleum refining presumably are industries that will consume at least the same amount of sulfuric acid in 1986 as they did last year.

Without those demand conditions, sulfuric acid production this year could fall below the projected 38.2 million tons. The lowest estimate likely would be 1 million tons less, resulting possibly from a larger slump in phosphate fertilizer use and less sulfuric acid consumed in nonfertilizer industries.

The phosphate fertilizer industry continues to be the key to demand for sulfuric acid. Phosphoric acid manufacture consumes more than 70% of sulfuric acid production, most of which is produced captively with energy from the burning of the sulfur recovered as efficiently as possible to improve the overall plant production economics. A large part of this phosphoric acid is exported, and another even larger part is made into ammonium phosphates, mostly DAP, of which a significant quantity goes to exports. Because the DAP market is so large, this single material appears to control the fortunes of sulfuric acid.

Because some past major buyers of DAP—India and China—have bought none in the first quarter and seem unlikely to buy more than a small quantity in the second quarter, 1986 exports of DAP are expected to decline substantially. The decline in DAP exports, plus lower use of fertilizers in the U.S. in 1986, will reduce wet phosphoric acid production to 9.5 million tons of P_2O_5.

The many uses of sulfuric acid outside the fertilizer industry generally are not going anywhere. The increased use of sulfuric acid to leach copper from certain ores and mine tailings is a bright spot. Leaching technology for copper helps the sulfuric acid market because it is a growing use and because it removes from the market acid that must be sold and therefore is priced low. Copper demand and prices have been weak, putting pressure on copper producers to cut costs by an increased use of leaching, which generally lowers costs. However, if copper demand rises, closed smelters could be restarted. And if sulfur dioxide controls required for those smelters' future operation are installed, increased smelter sulfuric acid could be produced, which would end the short-term prop for the sulfuric acid market.

Key Chemicals

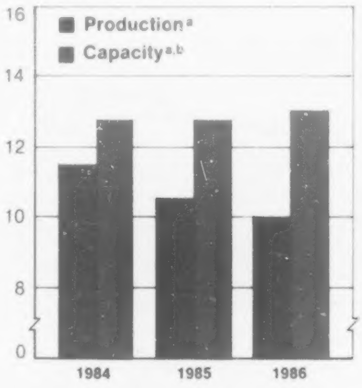
H_3PO_4

Phosphoric acid

- ***Production down again***
- ***Capacity up slightly***
- ***Prices holding***

PRODUCTION/CAPACITY

Millions of tons, P_2O_5



[a] Wet process and furnace acids. [b] First quarter.

MAJOR PRODUCERS

CF Industries, Freeport Chemical, Occidental Chemical, Texasgulf Chemicals, Williams Cos.

HOW MADE

Reaction of phosphate rock and sulfuric acid; burning of elemental phosphorus and subsequent reaction with water

MAJOR DERIVATIVES

Ammonium phosphates 60%, triple superphosphate 15%

MAJOR END USES

Fertilizers 85%, detergent materials 5%

FOREIGN TRADE

Exports—(as the acid) continuing strong at more than 1 million tons of P_2O_5, imports—remaining small at less than 25,000 tons of P_2O_5

PRICE

List about \$300 per ton of P_2

Lower worldwide demand for U.S. phosphate fertilizers will knock down U.S. production of phosphoric acid 5% or more in 1986. Both domestic and export demand for phosphate fertilizers will be down this year. Other uses of phosphoric acid—including that made from electric furnace-produced elemental phosphorus—will do no better than hold even, based on early forecasts.

If major foreign buyers of U.S.-produced fertilizers return to the market strongly in the second half of 1986, production this year could total 10 million tons of phosphoric acid as P_2O_5. That would be down 5% from the 10.5 million tons estimated to have been produced in 1985 and down more than 12% from the 11.4 million tons produced in 1984. If the major importers of such products as diammonium phosphate (DAP)—India and China—do not return to their 1985 buying level, then phosphoric acid production will decline to below 10 million tons as P_2O_5.

Capacity to make wet-process phosphoric acid by reacting sulfuric acid with phosphate rock slowly inched up in 1985 to about 12.4 million tons of P_2O_5. An additional 600,000 tons of capacity is based on burning of elemental phosphorus, and the product is called furnace acid. If some 9.5 million tons of wet-process acid are produced in 1986, the plant capacity available as the year began will run at an average rate of nearly 77%. Furnace acid operating rates will be somewhat higher.

The major additions to wet-process phosphoric acid capacity during 1985 were about 250,000 tons of P_2O_5 by Texasgulf Chemicals and less than 100,000 tons by J. R. Simplot. No significant additions to furnace acid capacity occurred last year. By the end of 1986, Monsanto will end its production of elemental phosphorus in Tennessee, but whether its furnace acid production will be reduced is uncertain.

Most furnace phosphoric acid goes into such end uses as detergent components (tripolyphosphates), foods and beverages, metal treating, and many small uses. As a group, uses of furnace acid are declining because of slowly tightening limits on use of detergent phosphates and changes in consumer product formulations. During 1986, that decline will account for part of the lower production total for phosphoric acid.

About 95% of wet-process phosphoric acid goes into fertilizers of one kind or another. The other 5% goes mostly into animal feed supplements, with a tiny amount being made into sodium tripolyphosphate for detergents. In 1985, more than 9.2 million tons of phosphoric acid as P_2O_5 went to fertilizers, either in the U.S. or in foreign countries. Sources indicate that more than 1 million tons was exported as either regular (54%) or super (70%) acids for subsequent use in fertilizer plants in other parts of the world, especially in the U.S.S.R.

In the combined domestic and export fertilizer markets, DAP accounts for the largest share of phosphoric acid consumption, at about two thirds of the total. Because phosphoric acid exports are a large fraction of all phosphate materials exports, DAP accounted for about 60% of phosphate exports on a P_2O_5 basis in 1985.

In late 1985, because their inventories were too large, India and China stopped their imports of DAP from the U.S. and have yet to restart on any scale. As a result, industry sources forecast that exports of DAP in 1986 could fall as much as a third, assuming that those two countries and others not now buying much will return to former purchasing levels in the second half of the year. More likely, sources say, exports of DAP will be down less than a third for the year. But the loss in exports will be too great to be offset by a better fall fertilizer season in the U.S., leading to the estimated 5% decline in phosphoric acid production for all of 1986.

Polyethylene supply and demand to remain in balance

A lot of polyethylene capacity came on stream throughout the world last year. And much more is scheduled to come on stream each year for the remainder of the decade.

But don't think the world will be wallowing in excess polyethylene capacity. "Overall, I expect capacity and demand will remain in close balance," says David M. Cheek, polyethylene marketing manager in Dow Chemical's olefin and styrenic plastics department. He outlined his worldwide polyethylene projections for the Chemical Marketing & Economics Division.

Last year, about 3.5 billion lb of polyethylene capacity was added to the world supply stream. That, says Cheek, is a lot of polyethylene. Equally important, much of that capacity was built in regions that had been strong markets for U.S. polyethylene over the years.

The leader by far was the Middle East and Africa, where more than 1 billion lb of polyethylene capacity started up last year. Most of it (82%) was low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE). Canada chipped in with 640 million lb of new polyethylene capacity, with about 62% of it earmarked for LDPE and LLDPE.

The only area to lose polyethylene capacity last year was Japan. As part of an industrywide rationalization program, producers there scrapped 356 million lb of HDPE capacity. That shutdown more than offset the 148 million lb gain in LDPE and LLDPE capacity.

Before the end of the 1980s, Cheek expects an additional 4.7 billion lb of polyethylene capacity to start up throughout the world, most of it planned for this year and 1987. Counting the plants that began operating last year, polyethylene producers will move into the 1990s with an additional 7.8 billion lb of polyethylene capacity.

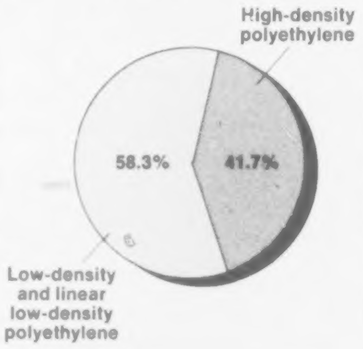
Some of this new capacity, of course, will replace existing plants, which either are or will become obsolete and unprofitable. But Cheek expects that most of it will become available to meet new worldwide demand. That prospect doesn't particularly bother him, however, because he sees demand growing in lockstep with the buildup in polyethylene capacity.

Cheek estimates that global polyethylene consumption last year was 47.7 billion lb, up 3.9% over 1984. If polyethylene demand maintains that 3.9% average annual growth for the rest of the decade, it will reach a hefty 57.8 billion lb by 1990.

Not all polyethylene growth will be equal, however. Cheek pegs the average annual growth of HDPE at 6.5%, but the combined growth of LDPE and LLDPE at only 2.5%. At those rates, 1990 consumption of LDPE and LLDPE will be 36.1 billion lb, and that of HDPE will hit 21.7 billion lb. Thus, HDPE's share of the total polyethylene market will increase to 37.5% in 1990 from last year's 33%.

"We're dealing with large-volume materials serving huge markets," says Cheek. Despite this, polyethylene is not a typical commodity product. Instead, he explains, marketers are dealing with dozens of differentiated products. Because of its size, the polyethylene market is considered mature. But Cheek thinks that it is also vigorous, with new products appearing frequently, each showing strong signs of continuing growth in sizable volumes.

LDPE, LLDPE dominate the polyethylene market



1985 U.S. consumption = 13.9 billion lb

Source: Dow Chemical

Some 3 billion lb of polyethylene capacity started up last year

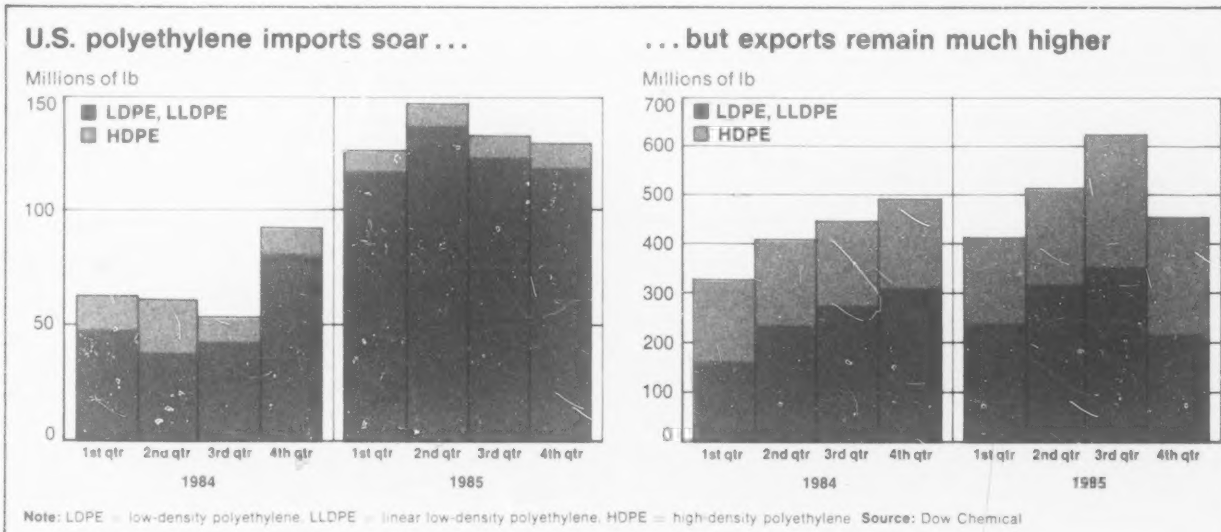
Millions of lb	LDPE & LLDPE	HDPE	Total
U.S.	483	180	663
Canada	395	245	640
Western Europe	159	—	159
Eastern Europe	—	176	176
Middle East[a]	838	187	1025
Japan	148	—	148
Far East[b]	55	—	55
Brazil	274	42	316
Latin America[c]	282	—	282
TOTAL	2634	830	3464

a Includes Africa. b Excludes Japan. c Excludes Brazil.
Source: Dow Chemical

Sizable volume is the key. When Cheek equates planned expansions in polyethylene capacity with average annual growth in consumption, the 7.8 billion lb of capacity being added during the second half of the 1980s turns out to be less than the demand increases projected for the period. For instance, the 3.5 billion lb of polyethylene capacity that started up last year represents only about two years of projected demand growth for LDPE and LLDPE; less than a year of demand growth for HDPE. The numbers get smaller—much smaller—as the 1980s wear on.

But that doesn't necessarily spell polyethylene shortages, either. The newer plants probably will be expanded with incremental additions to capacity. And sooner or later, says Cheek, the prospect of shortages will be strong enough to trigger plans and announcements for new polyethylene plants. Those announcements, of course, will depend upon how producers fare with profits, which have been a scarce commodity in the polyethylene business recently. Nevertheless, Cheek sees polyethylene supply and demand remaining in close balance for the rest of the 1980s.

In the U.S., apparent polyethylene consumption (U.S. production



Note: LDPE = low-density polyethylene. LLDPE = linear low-density polyethylene. HDPE = high-density polyethylene. **Source:** Dow Chemical

plus imports minus exports) hit 13.9 billion lb. That's a healthy 7.8% jump, almost twice the growth rate of the global average. On a volume basis, LDPE and LLDPE led the way, with 8.1 billion lb of material funneling into the market. But their combined growth rate of 6.6% still trailed that of HDPE, which surged ahead 9.4% to 5.8 billion lb.

Last year's strong increase in U.S. polyethylene consumption is "notable," says Cheek in an obvious understatement. The nearly 8% growth rate far outstrips what most forecasters are pegging for polyethylene's long-term growth—about 2.5 to 3.0% annually. More important, last year had been seen as one in which U.S. production would decline. Sizable new capacity came on stream in Saudi Arabia and Canada during 1984 and 1985. Output from those new plants was expected to appear on U.S. markets as imports. And they were expected to take a lot of business away from U.S. exports in third-country markets.

It didn't happen quite that way. True, polyethylene imports rose—they virtually doubled, from 273 million lb in 1984 to 540 million lb last year. But contrary to predictions, U.S. exports also climbed, rising a healthy 20% to almost 2 billion lb and giving the U.S. a 1.5 billion lb trade surplus in polyethylene. Those exports also helped U.S. polyethylene production to increase an estimated 5.5% last year, rather than decline as expected.

Cheek attributes the gain in exports to a mix of short-term and long-term factors. Plant accidents in Europe, for instance, are one short-term factor. Those accidents deprived some European polyethylene producers of their normal ethylene feedstock supply. That, in turn, created at least a temporary increase in demand for U.S.-produced material to service export markets.

Meanwhile, the impact of new polyethylene production outside the U.S. may take longer to be felt than originally expected. The increases in non-U.S. output were beginning to show up as U.S. imports last year, says Cheek. But he emphasizes "beginning." He believes that it will be some time before the full impact of the new foreign capacity can be measured.

The precipitous drop in crude oil prices, coupled with the sharply lower value of the U.S. dollar, will make U.S. polyethylene producers much more competitive with Middle Eastern producers. What's more, the marketing infrastructure needed to move large volumes of polyethylene from the Middle East still is limited, despite years of preparation. This, says Cheek, will change. But it will take time.

What will not change, however, is a need for conventional LDPE. Over the past few years, LLDPE has become the darling of the polyethylene industry. It is the major growth polymer. Significant gains also are forecast for production and consumption of HDPE.

Where does that leave conventional LDPE? Cheek believes large volumes will be produced and marketed for years to come. There is good evidence, he says, that products made from conventional LDPE can hold their own against LLDPE, based on performance in selected market niches. LDPE will continue to provide value, for instance, as a clarity monolayer film and as a key component in blends for specific applications.

Although demand for all of the polyethylenes will grow over the next few years, and supply will keep pace with it, there's no guarantee that the business will be profitable. If it wants to be profitable, a polyethylene producer must blend together four ingredients, says Cheek.

The first is a competitive raw material position. Cheek thinks that U.S. producers overreacted to the raw material cost position of Saudi Arabia, Canada, and Mexico. In retrospect, he says, U.S. producers are, and will continue to be, competitive, considering the real cost of capital in those areas and the costs needed to establish and maintain an effective infrastructure.

To be successful, producers also need a competitive conversion cost, and a commitment to both technology and marketing. Lack of an effective marketing apparatus probably explains the delayed impact of Saudi polyethylene, says Cheek. ☐

Amorphous polypropylene prospects look good

Amorphous polypropylene (APP) has gone from the unwanted coproduct of the polypropylene industry to a product that may now be worth producing on purpose.

The situation leaves polypropylene producers in a strategic dilemma. With the new high-yield catalysts now available, one strategy is to use technology that produces virtually all isotactic, or crystalline, polypropylene. The other is to continue finding new, growing uses for APP (atactic).

Last year, Eastman Chemicals division of Eastman Kodak opted for the latter. The company started producing additional volumes of APP in the first phase of a new facility. Newer variations will be available this spring.

But APP wasn't always that attractive, says Jack T. Mahaffey, Eastman's director of market management. In the early stages of the polypropylene industry, all plants produced an amorphous fraction as a by-product or coproduct. The amorphous portion ran from 2 to 15% of the total, depending upon the process and the catalyst.

Today, says Mahaffey, no plants in the U.S. are using 1960s technology. They get more crystalline and less amorphous polypropylene or they use new catalysts that produce no APP at all.

The problem, Mahaffey explained to the Chemical Marketing & Economics Division, was that no market existed for APP. Some companies burned all they produced. Others used it as landfill or dumped it in large pits. With a great deal of effort, a few markets for APP began to develop. It was a pretty good raw material for making adhesives. It could be blended with waxes and petrolatums for cable flooding compounds. And interest developed in APP as a paper laminating adhesive, particularly for kraft papers that were laminated and reinforced with glass fiber filament. Until then, asphalt had been primarily used to laminate papers for lumber overwrap, sealing tapes, furniture wrap, and pipe wrap.

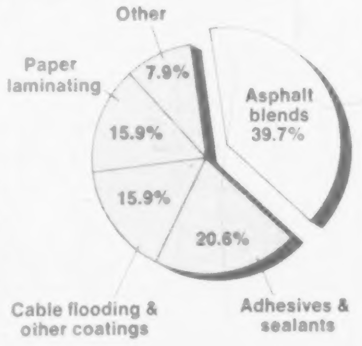
As paper companies switched from asphalt to APP, Mahaffey says, Eastman couldn't make enough APP to keep up with demand. Fortunately, the company still had its pit. Upon restart of mining the pit, the company remelted the APP in the pit, filtered it, cleaned it, and loaded it into tank cars. Other companies did the same thing. Eastman emptied its APP pit in 1984.

Meanwhile, APP consumption in the U.S. has been variously estimated between 130 million and 150 million lb in 1984. That includes imported and recovered materials and Mahaffey estimates that between 10 and 15% of the total was material recovered from the pits. He pegs last year's APP consumption at 126 million lb. But its end-use pattern has changed dramatically. In the 1970s, paper laminating was by far the largest end use, with cable flooding and adhesives next. Now, APP's largest use is as a modifier in asphalt for roofing compounds.

Since it became economically attractive for companies with APP pits to start mining them, the pits have been rapidly depleted.

Considerable amounts of APP are imported, says Mahaffey. But Italy, a historic leader in polypropylene, has essentially depleted all known inventories.

Asphalt blends take big share of APP market



1985 consumption = 126 million lb

Source: Eastman Chemical Products

Now, says Mahaffey, the industry has come full circle. It now may pay to produce APP intentionally. In some cases, old polypropylene units may be adapted to manufacture APP. But, because much of the equipment is old, these units may need significant retrofitting.

Today, by-product APP sells for 20 to 25 cents per lb in its dirtiest form and about 40 to 50 cents for the cleanest material. He says that newly made APP will sell for about 42 to 45 cents per lb in molten form and perhaps 5 cents higher as a solid.

Mahaffey estimates that last year's APP supply in the U.S. was 136 million lb. That includes usable recovered material. He thinks that production of by-product APP may have dropped to a 50 million lb annual rate at the beginning of this year. "There is a mixed bag of reports," he says, on how much is still in the pits in the U.S.

Eastman's APP plant at Longview, Tex., will make only a fond memory of the old pit. It uses a new process that doesn't depend upon the production of crystalline polypropylene as the old processes did. Direct synthesis should help Eastman become a readily available source of APP, says Mahaffey.

But he steadfastly refuses to forecast future demand. There are several ways of looking at it, he says. One is to assume that the markets can't afford the higher price of this APP. If so, producers have no incentive to invest money for on-purpose plants. Demand will equal supply, and alternative materials will be found to accommodate the markets.

However, another possibility is to assume there will be a pretty vigorous growth rate of about 15% annually for the next few years and that customers will pay the higher price. One big unknown is the supply available from European pits. Most pits in the U.S. have been exhausted or are well on their way. But not that much is known about the APP pits in Europe. Thus, supply reliability is a big question mark. □

PRODUCT REPORT

Aerosols Back on Road to Success

Aerosol cans produced by Metal Box in Sutton-in-Ashfield, England

Patricia L. Layman, C&EN London

The word is out around the industry: Aerosols are finally recovering from their long battle with adversity. In Western Europe, output growth in the aerosol industry is approaching 9% per year; in the U.K., output in 1985 was 11% higher than in 1984, according to figures just released by the British Aerosol Manufacturers' Association (BAMA). And when U.S. figures are published next month at the spring meeting of the Chemical Specialties Manufacturers Association (CSMA) in Chicago, they are expected to show an increase of 3 to 4% over 1984—the second year of growth in a row.

That, says Sam F. Copia, vice president of marketing for propellant supplier Aeropres Corp., Shreveport, La., means "the American public has given its stamp of approval to aerosols as a packaging form. I doubt whether any other package could have survived the attacks that the media leveled at aerosols," and, in some cases, still levels. "It is the most efficacious package that has been designed," he adds.

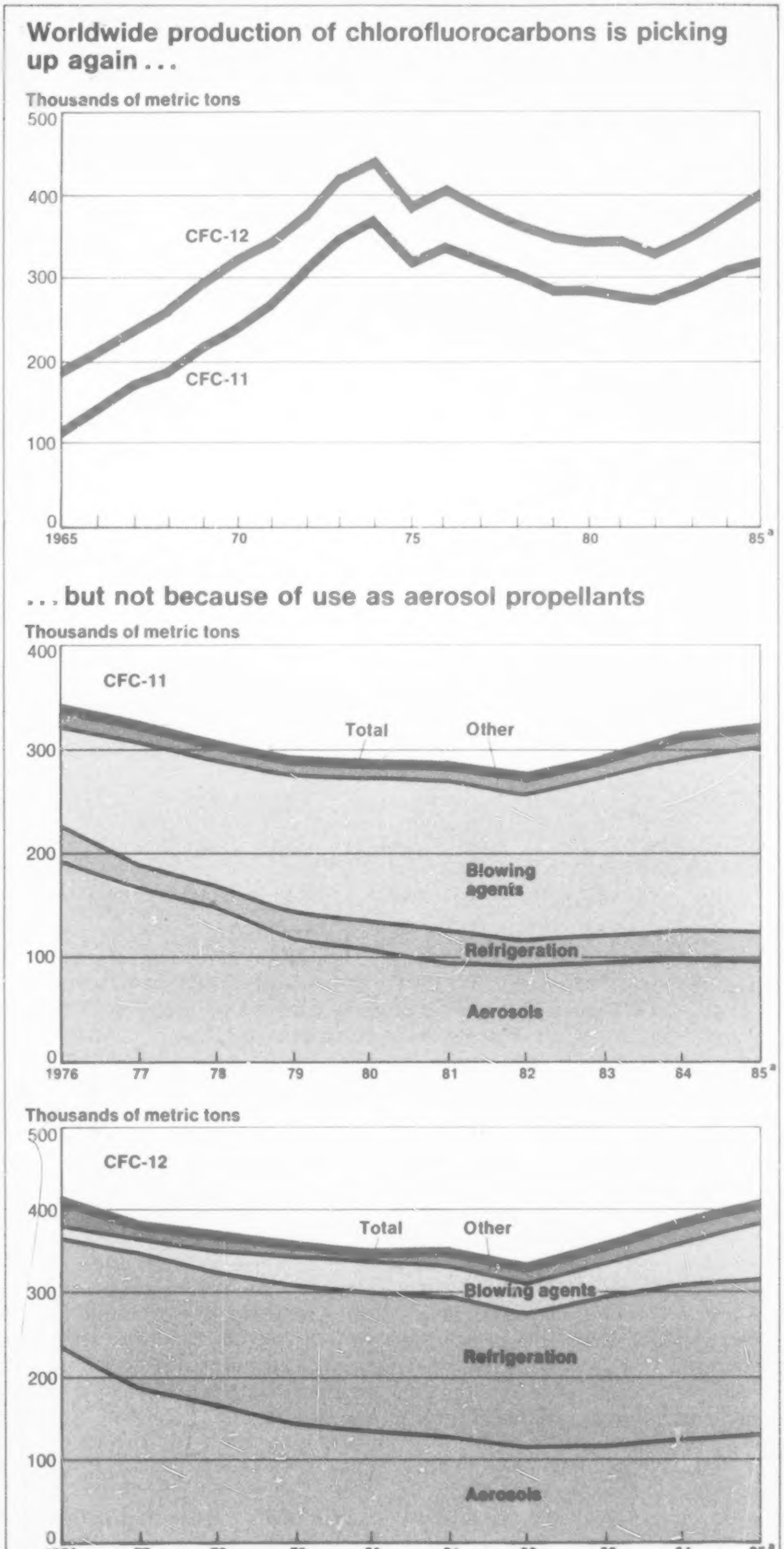
This is high praise for a packaging form that has been more accustomed to brickbats over the past decade. In fact, the general posture of the industry has been defensive, low-profile sheltering. But that is changing. From a lack of development in new technology and products, suppliers report they are seeing a rekindled interest in new systems and materials for customers' products.

That's good news for the chemical industry. In a sense, the aerosol industry is a strange bird. It views itself as unique. In practice, it is just one more packaging medium. That helps explain the reluctance of marketers to promote aerosols. They want to promote their own products. But, perhaps because the aerosol industry became intertwined so early on with chemical-specialty products, it has always had a strong association with the chemical industry rather than the packaging business.

The aerosol industry is a significant purchaser of chemical products in addition to the contents of the products put into aerosol cans. For example, it consumes some 250 million lb per year of hydrocarbon propellants. Aerosol hair sprays have boosted consumption of ethanol significantly over the past 20 years. The industry sometimes needs high-performance interior can linings. And many of the parts of an aerosol container are plastic, making these packages in turn a good customer of the chemical industry. The improving health of the industry, then, benefits chemicals as well.

Throughout its relatively short history, the aerosol industry has proclaimed a number of virtues for the package—ease of application, protection from contamination of the product, control of doses, and so on. According to work done for the British Aerosol Manufacturers' Association by product marketers themselves, aerosols in many cases are actually a more cost-effective packaging form for the consumer than other types of packaging.

Because of those benefits, the industry saw spectacular growth in the early days. But one problem was associated with that growth--aerosols are convenience products. Con-



Worldwide production of chlorofluorocarbons is picking up again . . .

. . . but not because of use as aerosol propellants

a Estimate. **Sources:** Chemical Manufacturers Association, C&EN estimates

sumers don't really need them. So when the whole chlorofluorocarbon-ozone controversy erupted in the mid-1970s, aerosols were hard to justify, and hence were vulnerable.

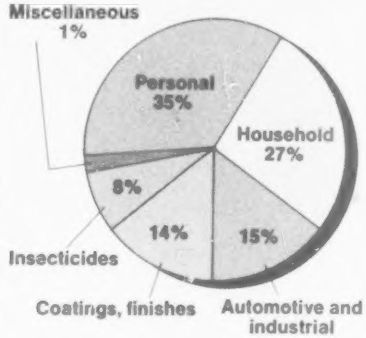
According to the theory put forward first in the early 1970s by University of California, Irvine, researchers F. Sherwood Rowland and Mario J. Molina, chlorofluorocarbons are not degraded under normal conditions, but persist to react with stratospheric ozone, breaking it down and destroying part of the ozone shield around Earth. The result is an increase in the amount of ultraviolet radiation reaching Earth's surface. The most obvious source of free chlorofluorocarbons was aerosol propellants. The way it was usually explained in the U.S. market, the consumer was faced with the choice of using an aerosol such as an underarm antiperspirant and causing depletion of the ozone layer and an increase in skin cancer, or using no aerosols and maintaining an intact ozone layer. Aerosols did not win out. Consumers believed all aerosols were contributing to air pollution, even though more than half the industry—55%—used hydrocarbons, not chlorofluorocarbons, as propellants.

In the U.S. in 1972, there were nearly 3 billion aerosol units filled; by 1975 the market was down to about 2.1 billion. It has been a long, hard slog for the U.S. market to come back to the 2.5 billion units expected to be announced by CSMA in May.

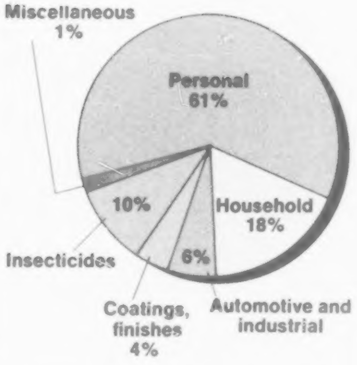
On the other hand, the aerosol industry in Western Europe used to look with awe at the massive numbers and growth in the U.S., but has long since ceased to do that. It never experienced the same pressures over chlorofluorocarbon propellants that the U.S. industry experienced, so did not suffer the same decline.

The Western European market is now quite a bit larger than that in the U.S., according to Figurama, a set of statistics published every two years by Metal Box, British packaging maker based in Reading and one of Europe's largest producers of aerosol cans. While many U.S. manufacturers and marketers were studiously avoiding innovation and

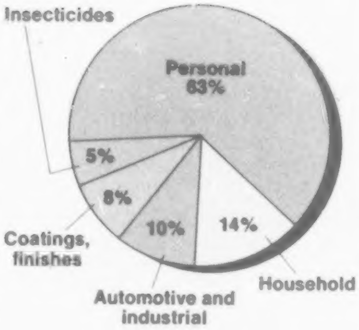
Nonfood aerosol products show different patterns



U.S. = 2.26 billion units,1984



U.K. = 626 million units ,1984



West Germany = 604 million units,1984

Sources: National aerosol associations in the U.S., U.K., and West Germany

new product development, Europeans went ahead. Now, new packages and new products are developed in Europe and then brought to the U.S.

One of the most spectacular cases in point is the mousse. The mousse may be, as one industry old-timer sniffs, old technology. But it came along at just the right time, with just the right products.

As Metal Box's Arthur Simpson, marketing manager for personal products and aerosols in the general packaging division, sees it, "The time was right, and also, L'Oreal got it right." On the Continent, he explains, about 90% of all hair salons are sponsored by hair-care product manufacturers, who supply chemicals and appliances. L'Oreal produced a hair-styling mousse for its salons, then received so many requests to sell it directly to its customers, that it eventually decided to do so. The foam technology was new for that market, and the product itself also featured a new resin that helped soften the keratin in hair, to give a quasi-permanent set.

From hair-styling preparations, the mousse technology is spreading into other kinds of products. For example, Elizabeth Arden has just introduced new mousse color makeup products. Other marketers are working on other lines—for example, body lotions and baby products.

Consumers in the U.S. liked the mousse products themselves and the packages as well. The cans were aluminum, imported at the time from Europe—slim, elegant, and more appealing than the chunkier tinplate cans typical in the marketplace. For the U.S., mousse products were a blessing to pull the industry out of its doldrums. As consumers bought, producers advertised more, and consumers bought even more.

Ironically, mousses have not done all that much for propellant suppliers because many of the formulations contain only about 5% propellant. Regular hair sprays, on the other hand, use much more.

Propellant suppliers, however, have benefited from the other major new product that found success in the marketplace—dry air fresheners. These have extremely high concentrations of propellant and very little solvent or oil. So they can be sprayed directly onto curtains or upholstery fabrics with little chance of causing fabric dyes to run or stain.

Dry air fresheners are an example of marketers working with researchers, notes Metal Box's Simpson. "The two have to work together. There had been complaints from consumers on the question of staining," so marketing requested a dry, nonstaining air freshener. "With hindsight, it was ever so easy to do," he says. "But when a formulation used to be 25% ethanol or white spirit of some light oil, some perfume, and so on, and now it is only about 1 to 2% perfume, and the rest propellant, that is a very different formulation."

Other market segments are also growing, but they tend to show different trends in different countries. For example, in the U.S., the market for personal-care products—particularly antiperspirants and deodorants—has always been stronger than in Western Europe. But correspondingly, the deocolognes that are a major category in Europe have not been very successful in the U.S.

In Japan, where the market is showing good growth, aerosol insecticides occupy a very high percentage of the market. The industry there has just taken a bash, however. The government has levied a new tax on the ethanol used in aerosols. And Japanese consumers have shown a fondness for alternative packages, such as pump sprays.

In Britain also, aerosol insecticides occupy a high percentage of the market. But that country, which prides itself on few mosquitoes and other similar insect pests, sends most of the aerosol products to the export market. Wellcome Foundation's Pif Paf insecticide, for example, is the leading brand in the Middle East, in particular, and is one of the major aerosol insecticides throughout the world.

All countries that produce aerosol products, however, are earnestly searching for new markets. For the British market, aerosolized foods are just becoming a significant category, following the success of aerosol whipped cream—a product that was

Methylene chloride: one lost, the rest saved?

In the aerosol industry, life has been one long struggle for propellants. First it was chlorofluorocarbons, cast under such a cloud of suspicion about possible ozone damage that they were eventually banned from all but a few exceptional uses. Now it is methylene chloride. Although at least one major aerosol end use—hair sprays—seems to have gone by the boards, others seem to be secure, albeit with increasingly strict precautionary labeling.

Aerosols accounted for 24% of the 584 million lb of methylene chloride consumed last year in the U.S. That's slightly less than methylene chloride's major use—paint strippers, which held 28% of the market—but more than twice as much as the next leading market segment, degreasers.

Methylene chloride is used primarily as a solvent for the materials being propelled. Other solvents can be—and have been—used, of course. But methylene chloride has one major advantage: It is nonflammable, and it suppresses the flammability of other chemicals in the formulation. It also functions as a vapor pressure depressant, and as a viscosity thinner.

Hair sprays have been one of the most visible aerosol markets for methylene chloride. Used at up to about 25% of the formulation, the chemical provides solutions of the film-forming resins, and depresses the cloud point of resins in both alcohol-hydrocarbon and alcohol-carbon dioxide systems. Other aerosols dependent upon methylene chloride are coatings products, some of which contain as much as 35% methylene chloride, insecticides, and a variety of other household products.

One of the major attractions of methylene chloride, then, is its safety action as a flame suppressant. So it is ironic that it has run into problems on safety grounds—in particular, carcinogenic testing. Last year, animal tests conducted by the National Toxicology Program in an inhalation study at several thousand parts per million showed several positive results. Specifically, mice tested at the exposure levels of 4000 ppm developed malignant tumors. Rats developed benign tumors in the mammary glands.

A variety of tests on a variety of animals, such as hamsters and rats, were run on methylene chloride over the years, none of which indicated a problem. At least two epidemiological studies—one by Celanese on about 1200 people, and a second by Eastman Kodak on about 1000 people—have been negative. And European marketers are optimistic about a study on the chemical there, early indications of which show no problem.

According to Paul A. Kammer, executive director of the Halogenated Solvents Industry Alliance (HSIA), Washington, D.C., the industry cannot quarrel with the results of the test by NTP. There is serious question, however, about the validity of the test results, given the exceptionally high exposure levels, and the strain of mice used in the study.

"That strain of mouse is very prone to tumors," he says. "We aren't sure what we are looking at."

HSIA, with a membership of about 150 suppliers and users of halogenated solvents, believes that a more scientifically sound approach is to study the metabolic pathways of chemicals in various species. Kammer cites studies that Imperial Chemical Industries is doing in the U.K. to trace the different routes by which methylene chloride is metabolized in various species. "One of the metabolites in mice is carcinogenic; at human inhalation rates, we don't see that metabolite. That is one reason, we think, why we don't see cancer in humans. This is changing the way people do risk assessments: People are learning so much more about how chemicals can work."

In the meantime, however, the positive study on methylene chloride has caused a great deal of distress among government regulatory agencies (C&EN, March 17, page 17).

The Food & Drug Administration has taken the swiftest, harshest action. It has proposed a ban on the use of methylene chloride in hair sprays, over which it has jurisdiction. It said it proposed the ban to protect "those facing the greatest risk from such products," an estimated 300,000 people in the U.S. employed as licensed hair-care specialists, who use hair sprays in their work. To a lesser extent, there could be health hazards for the millions of people who regularly use aerosol sprays that contain methylene chloride on their own hair, FDA added. (On the other hand, it is trying to avoid banning methylene chloride as a decaffeinating agent for coffee, on the grounds that the risk would be so small as to be trivial.)

The other U.S. agency with jurisdiction over methylene chloride in aerosols is the Consumer Product Safety Commission. The commission has particular jurisdiction over insecticides, automotive and coatings products, and other household products. CPSC at first considered restrictions on the use of methylene chloride in aerosols. But now, reports HSIA's Kammer, "I'm getting optimistic about methylene chloride. Nobody at CPSC is talking about a ban any more. They know the data aren't there to back it up. The action will be for improved labeling—for adequate ventilation, for example, and for point of purchase pamphlets on how to use the products properly. I think they will buy it," as an alternative to a ban.

That doesn't necessarily displease Kammer. After all, he says, methylene chloride is one of the safest products around—but people need to use it safely.

launched and buried once before 10 years ago.

In the U.S., aerosol pharmaceutical products are becoming a hot topic in the R&D labs, industry observers report. Mousse technology, for example, could be used to produce edible whipped foams—perhaps just the thing to serve up medicine in, to a recalcitrant child. The pharmaceutical industry, says one supplier, is finally beginning to understand the benefits of aerosols. They make the package less accessible to children, there is no air inside to contaminate the product, and they are nonspilling and easy to dispense.

Moreover, the development of aerosol forms of an existing pharmaceutical can be one way for drug companies to extend the patent life

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In a sense, the aerosol industry has become accustomed to the controversy about chlorofluorocarbons. It is an ongoing debate that has become part of the industry, for better or worse. But other threats aimed at the industry are more immediate and more worrisome. Some industry observers are concerned that eventually these threats will take on the same weight and magnitude that the ozone-chlorofluorocarbon issue had.

The major concern for U.S. producers is smog and how hydrocarbon propellants contribute or do not contribute to its formation. The California Air Resources Board has begun to consider legislation to control the use of hydrocarbon propellants in aerosols, as part of its efforts to control hydrocarbon emissions and smog formation.

As early as September 1982, members of CSMA, the major aerosols trade group, testified at hearings before California's Bay Area Air Quality Management District board of directors, to contest such action. In the CSMA testimony, given by Roger Beutner, vice president of manufacturing for Amway Corp., the association argued that those who favored the proposed ban overestimated the current emissions from aerosol hydrocarbons; thus, it would not accomplish what they hoped. Moreover, the association said that the measure would not be cost-effective. CSMA claimed that it would have a negative economic impact on the industry at least 60 times greater than estimated and that it unfairly discriminated against aerosols vs. other nonaerosol products.

Since 1982 the issue has not died, however. If anything, pressures have become stronger. California is concerned, of course, not just about aerosols; it is also tightening controls on emissions from automobiles, from paints and coatings, and so on.

But aerosols are a convenient target to control. For example, California authorities figure that because

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there are alternatives to aerosols for such applications as hair sprays and antiperspirants—for instance, pumps and roll-ons—consumers can do without aerosols. Other categories, such as aerosol paints and insecticides, are also being investigated. Notes one marketer: "This may eventually come to equal the magnitude of ozone—we don't know yet."

If California were isolated, the controversy might not be all that bad. But California's actions tend to ripple outward, so they eventually could affect the industry across the U.S.

That is the air-pollution front. The industry is also fighting smaller battles around the country on such grounds as storage of filled aerosol stocks and "antisniffing" legislation in Texas, in particular. (Sniffing refers to the practice of sniffing some aerosols to produce a "high.")

But it may give U.S. producers some comfort to know that their situation is shared by their international colleagues. For example, the issue of storage is the U.K.'s cause célèbre at the moment, reports David Roberts, director of BAMA. He relates a saga that begins with the formulation, by the British Health & Safety Executive (HSE), of a program for notification concerning installations handling hazardous substances. HSE decided that facilities with more than a specified number of tons of particular chemicals would have to notify the agency. The program was developed as part of regulations to isolate those chemicals that could be involved in major industrial accidents.

"The level for butane was 25 tons," recalls Roberts, "and we advised our members that it would affect bulk stocks only. We were horrified when HSE decided that it would also affect butane in packaged stocks. That brings in people with less than 25 tons of bulk stocks but with commercial warehouses. If you are, for example, Sainsbury's [a major British supermarket chain] with a central warehouse, you would have to go to each supplier and ask, 'How much hydrocarbon is used per can?' You would have to compile figures and compute if you are over or under."

BAMA met with HSE, and, ac-

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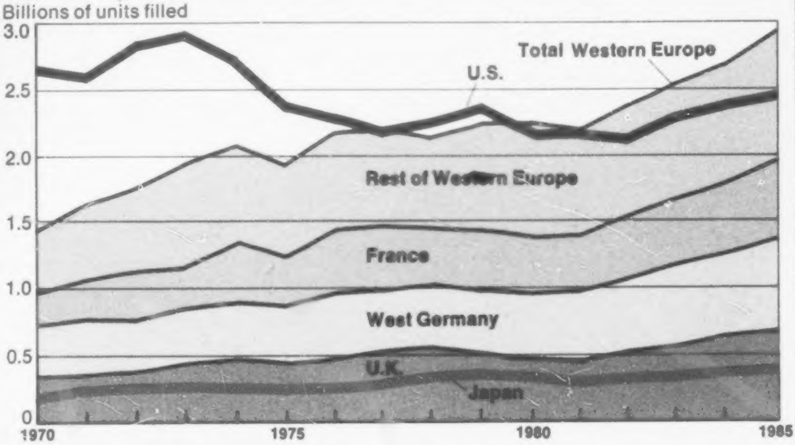

Sources: Metal Box, British Aerosol Manufacturers' Association, C&EN estimates

cording to Roberts, was told that the group should prepare a case, and HSE would work out an exemption. A draft report went back and forth several times. It was eventually submitted to HSE, which held the submission for three months, then turned it down and said, "Everybody's got to notify in three days."

The group decided to appeal on the grounds, basically, of proportional risk. "Yes, an aerosol warehouse will burn nicely," concedes Roberts. "But this isn't Seveso." BAMA went to judicial review, where HSE argued that the ruling wasn't a "directive," merely an "advise." "They sought on a technicality not to get a ruling; they didn't want the rule to be clarified," says Roberts. "We've written to our members that we don't think this applies to packed aerosols, so ignore it. So it is now back in HSE's court."

Other draft regulations in Britain apply to building regulations, with notices for fire brigades if more than 25 tons of dangerous goods (including flammable aerosols) is aggregated.

European Economic Community regulations have led to the formation of rules to follow for accident plans. In the case of aerosols, if more than 200 tons of butane is stored, a company must have an accident plan, inform neighbors, staff, and so on. However, various countries are interpreting the rules in different ways. Many are applying them only to bulk stocks, not to stocks of packed aerosols.

One of the results of the U.S. industry's facing so many battlefronts is the formation, within the past year, of a new industry group, the National Aerosol Association. The major force behind the group is Aeropres' president Sam Copia, one of the founders. He reacts angrily when told of what he feels are misconceptions by U.S. industry and trade media alike that the group was formed as a competitive trade group to CSMA.

"Anything that promotes aerosols won't rival any other organization that promotes them," he argues. According to other sources, the main aim of the group is to educate the general public about aerosols. The original founders thought, they say, that CSMA had become too absorbed in fighting the battles of methylene chloride and California's air emissions standards to publicize the positive aspects of aerosols. And many in the industry believe that promoting the positive features of the aerosol package is what has been sorely needed for a number of years.

As mentioned earlier, for the U.S. aerosol industry, the controversy over chlorofluorocarbons gave only the final push to a switch to hydrocarbons that had begun years earlier. At the time of the controversy, hydrocarbons already were being used in some 55% of all aerosols filled because they were less expensive than fluorocarbons. When

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the Environmental Protection Agency eventually banned chlorofluorocarbon propellants, however, most of the rest of the industry switched over. Only a very few exemptions, such as pharmaceutical aerosols, were permitted.

It was a traumatic time. The industry was suddenly faced with the need for massive capital investment in new filling equipment. Marketers were faced with an abrupt need for reformulating. And consumers took some time getting used to what were different products with slightly different characteristics.

As a result, sales slumped a third. Marketers were quick to drop chlorofluorocarbons, and, rather than attempt to educate the public on the differences between the two kinds of propellants, some dropped aerosols altogether. Alternative product forms abounded—pump sprays for hair spray and window cleaners, and stick and roll-on forms of antiperspirants and deodorants.

Sales are slowly working their way back. But for an industry that once reveled in growth rates of 8 to 10% per year, 2 to 4% is excruciatingly slow. As seen through European eyes, "The U.S. is still suffering," Metal Box's Simpson observes. "In the mid-1970s, the markets moved away from aerosols because of the 'pollutant' taint. Scientists are still arguing, and they are no further forward."

The shift, however, has left hydrocarbons the mainstay of the aerosol industry. The major suppliers are Phillips 66 Co., Bartlesville, Okla.; Diversified Chemicals & Propellants, Chicago; and Aeropres Corp. Aeropres bills itself as the largest supplier to the aerosol industry, particularly with the boost to its business it received when it purchased Industrial Hydrocarbon's capacity several years ago.

Though growth is slow, it is growth, and some suppliers can even report that business has been excellent. Growth has been very modest over the past two years, points out Richard Frauenheim, president of Diversified. "But it is good to be going back up."

Given the abrupt shift the U.S. industry went through and its aftermath of market decline, European suppliers have tried to hedge their bets for all possibilities, no matter how unlikely or unwelcome. Notes Roberts of BAMA, large fillers in the U.K. have put in hydrocarbon facilities. This gives fillers the opportunity for total substitution if needed. But blending with chlorofluorocarbons has been the favored route to meet the 30% reduction in chlorofluorocarbons required by EEC. They prepared, adds one supplier, for a "worst-case" situation: being forced to abandon chlorofluorocarbons. If an abrupt switchover were required, they would have to invest more rapidly than usual. This way, the investment already has been made at a

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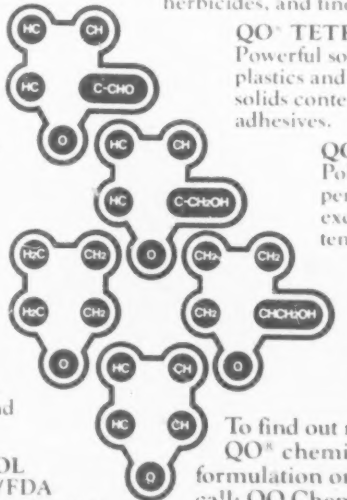

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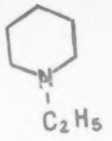
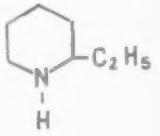
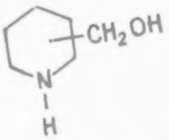


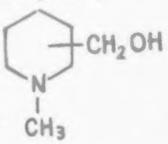
2-Ethyl-piperidine



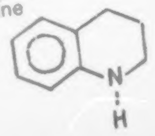
Hydroxymethyl-piperidine



N-Methyl- hydroxymethyl-piperidine



1, 2, 3, 4-Tetrahydro-quinoline



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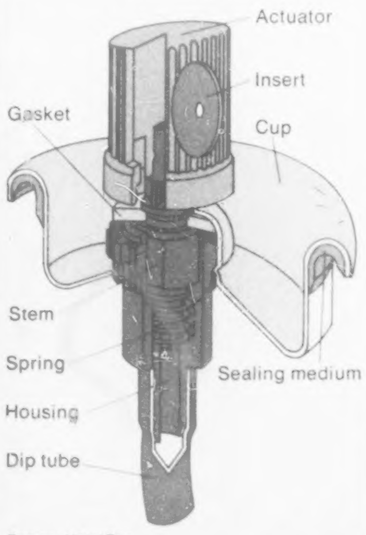
more controllable pace. All major fillers in the U.K. can use hydrocarbons, but most use mixtures, not pure hydrocarbons.

European marketers and consumers, suppliers contend, find that the substitute propellants give less acceptable products. They worry about consumer hazards, with flammability. But most of all, marketers worry that if they continue to reduce their use of chlorofluorocarbons, consumers will turn away from aerosols altogether. They fear that their sales will drop off just as dramatically as the U.S. aerosol sales did in the mid-1970s.

"On purely economic grounds, there are merits in using hydrocarbons. But chemists say the formulations don't have all the properties of those with chlorofluorocarbons," says Metal Box's Simpson. "The U.S. government used consultants to indicate how much money would be saved by switching to hydrocarbons—but the industry went down by one third."

With that kind of resistance, it will take some selling to open the hydrocarbons market in Europe. That's a challenge Diversified's Frauenheim is willing to take on, however, to share in the European industry's growth. The company is building a plant in Krefeld, West Germany, just outside Düsseldorf,

Aerosol mechanism: a lot in a little package



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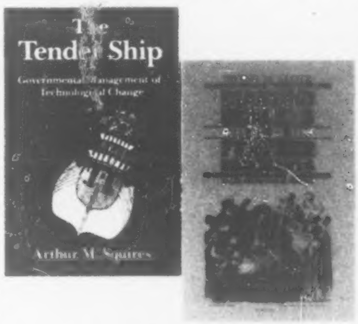

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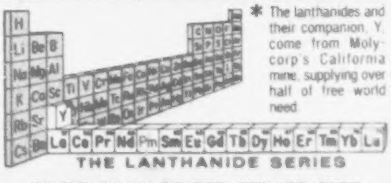

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for producing hydrocarbon propellants. "We also will be marketing fluorocarbon propellants and some foam-blowing agents," says Frauenheim. The plant is under construction and will be operational by this fall.

"I don't think it will be difficult selling hydrocarbons in Europe," he contends. "It's our opinion that companies in Europe are experiencing the same thing U.S. companies did in the 1970s. They are being told by fluorocarbon marketers that hydrocarbon propellants are not of proper quality. We have managed to convince them here that that is not true. Once they've changed, some products are even better. We have the background and experience, and with our technology, products will be even better than they are now."

Some European industry executives would argue that that is a U.S. view of the situation. In Europe the industry has used butane in household products since the 1960s. And it has made extensive use of propellant blends.

Nonetheless, other suppliers continue to work on new propellants and propellant blends. A case in point is Du Pont, who is touting dimethyl ether propellant to the aerosol industry. The company has been selling commercial quantities of the propellant since 1982, but has found market penetration slow in the sluggishly growing business.

But Du Pont's Don Dunn, sales manager for its Dymel line of aerosol propellants, reports that business has begun looking healthier over the past year. Dimethyl ether and other specialty propellants are potential replacements for methylene chloride and can be used to make water-based, nonflammable systems, he believes. They also reduce the flammability of solvents and of systems with high concentrations of propellants. "Companies are trying to look at other technologies, other chemistry, to have options just in case the government forces them to move. They want something to move to," he says.

"When we introduced our products three or four years ago," Dunn says, "they were new, and we were trying to convince people to switch. That's always difficult for products that generally cost more. Now we are through that stage. New products are coming in for which their manufacturers have considered all the options. We are in at the base-building point." That can be a long, time-consuming process, he points out—several years to develop a new product, test the propellants and solvents in a formulation, determine how the product ingredients react with them, test for any reaction with the container or container lining. "It actually is very difficult for a marketer to get a new product out because so much is at risk."

There is also some interest in these new propellants among European marketers, particularly of fragrances, who want to export directly into the U.S. and into European countries that restrict chlorofluorocarbon use without changing propellant and formulation. The new propellants can be used to meet any regulations anywhere, allowing a one-time-only multinational formulation (C&EN, April 29, 1985, page 19).

Changing formulations and making product innovations may be one way for the industry to bring about its own revitalization. Things are picking up in the marketplace. In Western Europe, sales are sparkling. British aerosol manufacturers are gratified with 11% growth in 1985. On the Continent, sales are expected to approach double-digit rates. Even in the U.S., with the slow growth that industry has seen over the past several years, the situation may be improving. It is possible to detect hints of enthusiasm that were missing during the industry's beleaguered years. Key to the revival are new or better products—not necessarily those put into aerosols, but the aerosol components products are put into.

Industry veteran and valve consultant Walter C. Beard, for example, says he is "more excited about the industry now than when I started 35 years ago." The reasons for his enthusiasm are the new valves he has invented and licensed to Bespak, British manufacturer of specialty valves, for marketing in Europe. He is also negotiating with Bespak a license for marketing the valves in the U.S.—Bespak is building a new plant in North Carolina—and in the rest of the world.

A number of valves are involved: special metering valves to work with any pressurized system; high-flow valves for viscous materials and beverages; specialty protective valves through which air cannot get at the contents of the package. These valves are particularly good for protecting moisture-sensitive products. Beard, based in Middlebury, Conn., is also working on a series of valves especially for plastic containers, which he thinks have a bright future in the aerosol industry. "There is a lot going on here and in Europe with plastic containers," he notes.

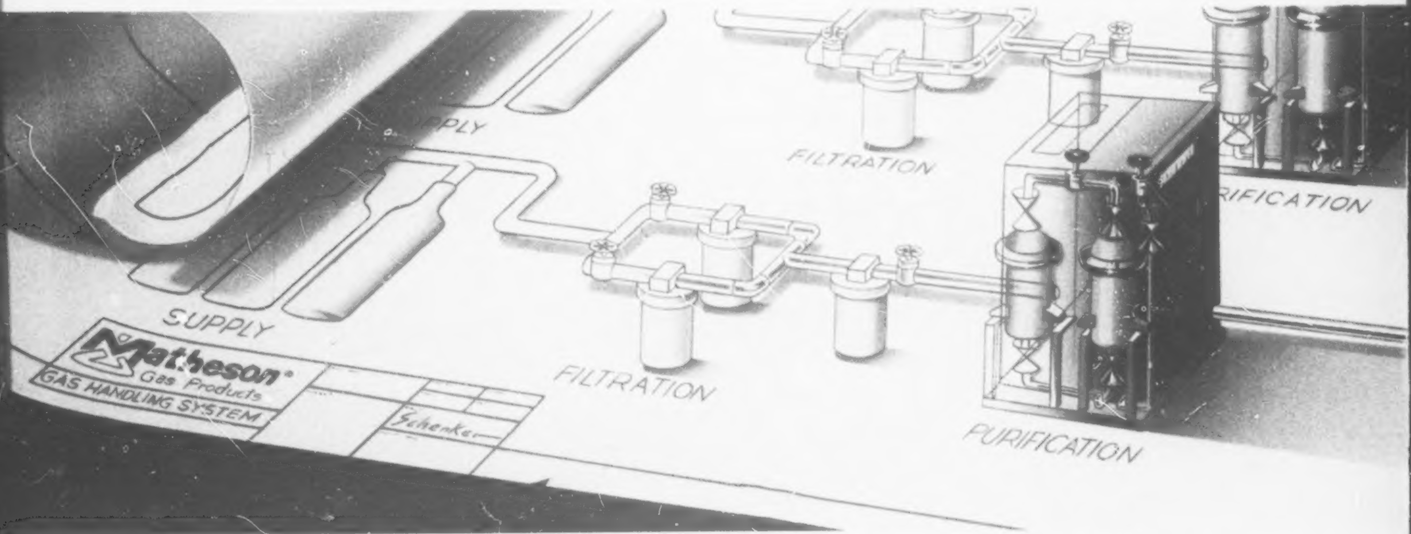
That's the kind of belief in new packaging that pleases Wheaton Industries, Mays Landing, N.J., which has launched a new aerosol container made of polyethylene terephthalate (PET). Plastic containers are not a new idea: Celcon acetal copolymer was highly touted in the 1970s, but went nowhere commercially. It and polycarbonate were very expensive, says Bob Shiels, executive vice president and general manager of Wheaton Aerosols. "We had hoped that, at some time, they would be feasible because the resin price would drop. But the prices never did. Also, Celcon never did do a lot of what we needed to do. It was a bit brittle and needed to have thick walls to get the barrier properties."

PET, on the other hand, is a good barrier, Shiels explains, especially for carbon dioxide. This is the reason it has been adopted by the beverage industry. Drawing from Wheaton's experience in the industry, Shiels says, "We learned a lot. PET is a good, stable resin, easier to work with, and do more with, than Celcon. We thought we saw a problem with crystallinity, but it looks now as though that is not a problem." Customers will have to test their formulations in the new package, he notes, but that's a standard pre-

Newest U.K. figures show encouraging growth

Millions of units	1984	1985	% change
Hair care products	140	182	30%
Personal deodorants, deocolognes, antiperspirants	104	115	11
Medicinals, pharmaceuticals	66.5	69	4
Insecticides	64.5	63	−2
Waxes, polishes	52	50	−4
Air fresheners	40	45	12
Colognes, perfumes	42	41	−2
Paints, lacquers	22	24.5	11
Automotive products	23	24	4
Shaving lather	20.5	23	12
Industrial products	12	13	8
Starches, fabric finishes	9	10.5	16
Miscellaneous	12.5	19	52
TOTAL	**608**	**679**	**11%**

Source: British Aerosol Manufacturers' Association



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caution whenever a new package is adopted.

Wheaton's specialty in the industry is glass bottles. So despite what some metal-can producers think—that PET will be limited to small, specialty packages, much as glass is now—PET is "definitely a replacement for cans," according to Shiels. "Glass is vulnerable for some uses, especially where there might be breakage problems. But not really, in the fine end of the cosmetics and toiletries business. Do people want plastics for those products? For a high-priced fragrance, glass has an ambience all its own," he adds, explaining why he won't set the two in competition.

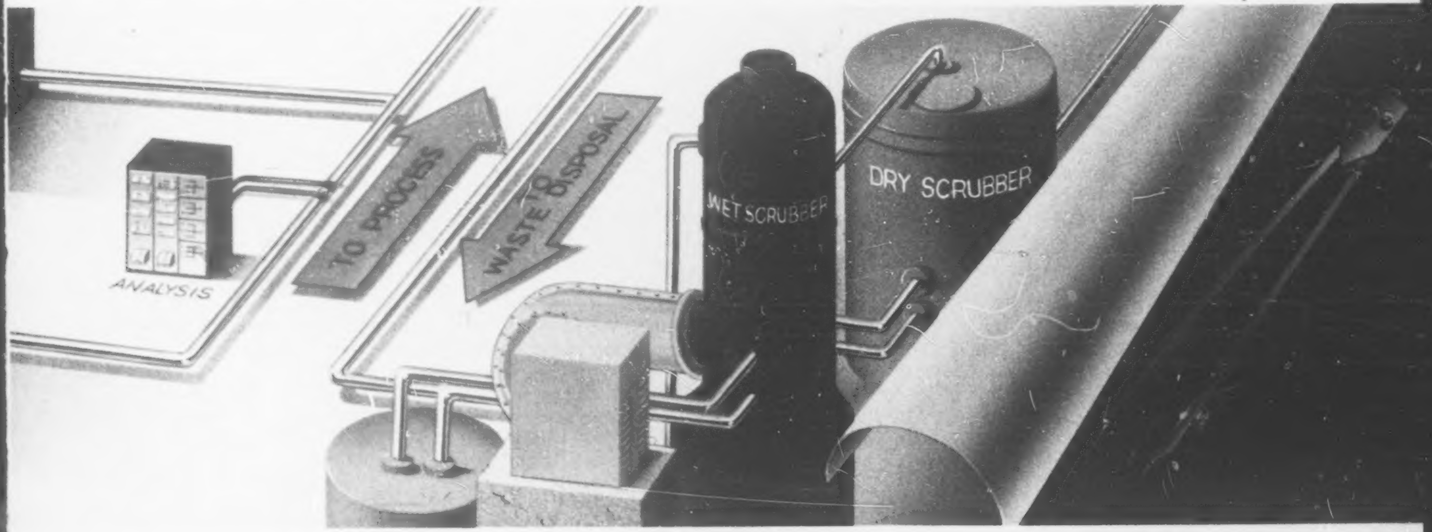
He is aiming to use PET containers as a substitute for metal cans. He claims that PET containers have weight advantages and can be made in different transparencies from completely transparent through translucent to opaque "in all colors of the rainbow." Also, they do not corrode and therefore require no interior linings. And because the container is blow-molded, various surface effects can be molded in, such as hobnailing or diamond patterns. Currently, the economics of PET containers are roughly those of aluminum cans, or perhaps even a little poorer. "But even if PET containers are the same price, and you can get rid of problems, they are worth it."

One of the problems, as many suppliers see it, is that there is a shortage of people actually familiar with aerosols and aerosol technology in product design. That is true particularly in relatively untapped areas such as the pharmaceutical industry. Only a few universities have strength in teaching aerosol technology. Long Island University in New York has courses and seminars on aerosol technology, under the guidance of former dean John Sciarra, who is a consultant in the industry and a frequent contributor to the specialty trade magazine *Aerosol Age*. And in the U.K., the University of Sussex in Brighton offers a degree in pharmacy that includes a one-year course on aerosols.

Those formal programs are rare, however. Far more commonly, people learn the business through their on-the-job experience. "It's quite a crazy situation," complains Metal Box's Simpson. "There just are not enough people with the vision to know what you can do."

That's not to say the industry sits around doing nothing. But the research and development that is done often seems to be accomplished in fits and starts. In the U.S., much of it has been purely defensive over the past decade, consisting of attempts to defend the market that existed, rather than design for new markets.

One of the fits and starts deals with can production—specifically, welding the seam down the sides



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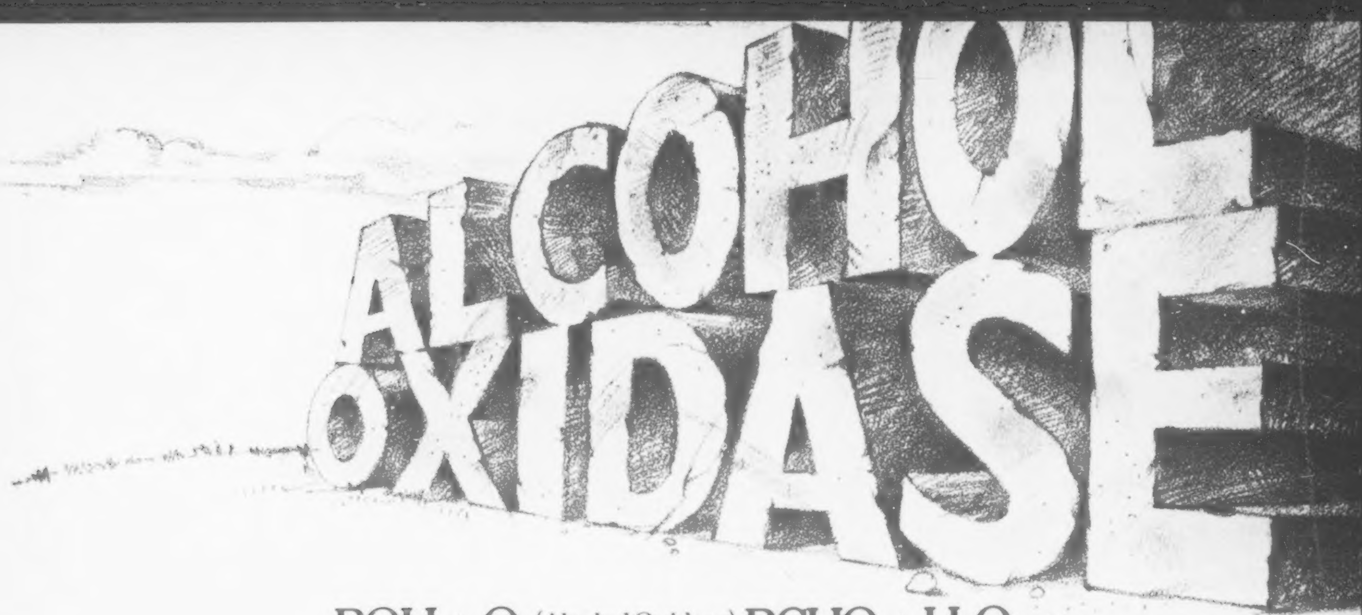

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on tinplate cans. For example, some research has been done on laser welding of the cans, which would eliminate even the thin seam that now shows.

But primarily because of the competition between tinplate and aluminum cans, more work has been done on improving the existing package designs. For years one aerosol can looked much the same as any other aerosol can. However, the situation in the U.S. differed somewhat from that in Western Europe.

Historically, the U.S. industry has used tinplate, with some glass as specialty packaging. But in Western Europe, the first aerosol cans were aluminum. The U.K. had built tinplate capacity by 1953, whereas in West Germany, soldered tinplate was not really available for aerosols until the late 1950s. By that time, aluminum had a firm grip on the European market. In West Germany, aluminum now holds 55% of the aerosol container business, compared with 40% for tinplate and 5% for glass. In the U.K., tinplate accounts for 75% of the market, aluminum 15%, and glass 10%, says Metal Box's Simpson.

It was the aluminum can used by European designers that was responsible for a great deal of the success of the mousse products that rejuvenated the aerosol industry, both in Western Europe and the U.S. The aluminum cans, marketers feel, have more of an "up-market" image than the old tinplate and are more aesthetically appealing to the consumer.

Contends one marketer, for example, "In Europe, aerosols have moved out of the commodity business. They now look nice. Even the products for use with a car are nicely presented. In the U.S., aerosols have been very much a commodity item—they have looked scruffy. They aren't sold as something desirable. They are sold as something needed. Therefore, the price marketers could get for the product was just a little bit less. It may be just a matter of pennies, but it makes all the difference to the bottom line."

Suppliers of chlorofluorocarbon propellants at Imperial Chemical Industries would agree with that. Says Stuart Kelly, whose team compiles filling statistics from Western Europe and the U.S., "We originally started these papers with the thought that the U.S. was the pointer to what would happen in Europe. The situation has completely turned around: Now the technological innovations and marketing initiatives are Europe-led. They are very much picked up and copied by the U.S."

The elegant aluminum cans from Europe have spurred the tinplate-can makers into brushing up their own act by refining their products. The most recent major development to be commercially successful for tinplate is the "necked-in" can, which features a can neck that is taper[illegible] just a bit, so that when the cap is put on, it makes a smooth line from top to bottom. There is no ridge where cap meets can.

According to Simpson, Metal Box now produces six of its necked-in Trimline for every one regular can. "Over 90% of our cans are Trimline.

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We've gone almost completely to that, even though there is no difference in price. The cans just look better."

The new designs also have a coincidental advantage that appeals to marketers. The elimination of that minute ridge around the can means that distributors can get up to 10% more product on a truck.

Also, the new cans can be made in smaller sizes. This is important for keeping up with the current down-sizing trend in Europe. Says Simpson: "We are using proportionally more capital for the smaller cans, but they have got the marketer into product sectors he hadn't been in before—small cans for handbags, for example, or for suntan products—where people don't want really big cans."

Tinplate cans sell primarily because of cost advantages. They are 10 to 25% cheaper than aluminum cans. Also, tinplate-can manufacturers claim that printing is superior on tinplate. "The printing is better because you are actually printing on the flat. With aluminum, you have to print on the round," explains Simpson.

However, just as competition from the aluminum-can makers have forced tinplate-can manufacturers to sharpen their own capabilities, the graphics on aluminum have improved because of competition from tinplate. "They're doing much better than they were; they can do six- or seven-color printing now," Simpson notes.

The result is that new technology is moving to the U.S., where can makers see a better package. "It may still not sell them more cans, but it will prevent aluminum from continuing its inroads," Simpson says. "It's exactly the same situation we had in Europe. The marketers had a choice, so we the tinplate makers had to make better packages."

U.S. aerosol can production has been dominated by the can companies—National Can and Continental Can, in particular—and Crown Cork & Seal. Metal Box is the major supplier outside the U.S., selling from its U.K.-based headquarters to some 60 countries. It has sold to the U.S. for about three years. When mousses were first introduced in

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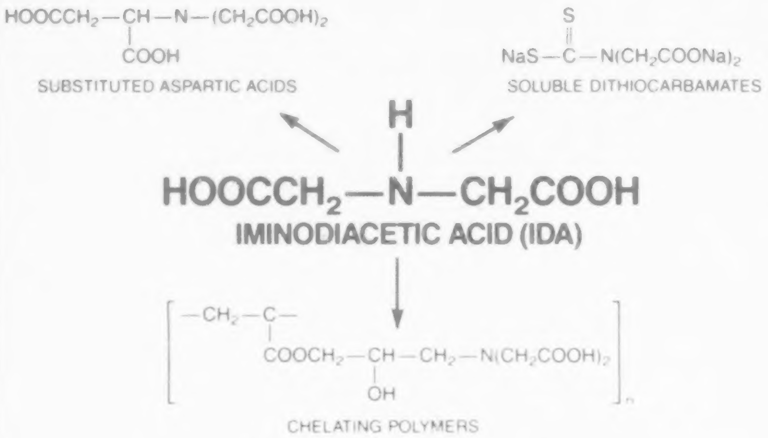

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their aluminum containers, all the aluminum cans were being imported. Since then, however, a number of aluminum-can production lines have been built by U.S., Canadian, and European producers. France's Boxal, for example, has built three production lines, and others have added to what probably is now overcapacity.

"Nobody is at capacity. There will be as many aluminum cans as you want, in the foreseeable future," says one observer. "The mousse market has stabilized, and some [companies]—L'Oreal, for one—are still importing cans. There is no trend toward pretty aluminum just because of aesthetics." On the other hand, he adds, "I haven't heard of any price cuts," so things cannot be too bad.

Overcapacity but no price cuts—these are just two indications of an industry, particularly in the U.S., that is getting back to normal after a breathless several years scrambling to fill demand for containers and filling capacity. The European scene is already well supplied, and the U.S. is quickly becoming so. And the players are no longer strictly national companies.

Instead, suppliers are becoming increasingly international to better serve their customers, the international marketers. Aerosol plants will become bigger and more consolidated. Can production in Ontario may serve the U.S. or Taiwan; production in the U.K. may go to Egypt or Kenya; production in France to New York. Fillers will find their products going farther afield—a U.S. marketer filling products there for a destination in other parts of the world, for example, or a French marketer filling in France, then sending product to the U.S.

In other words, innovative and styling trends may have ceased to be dominated by the U.S., and the business itself is moving away from a one-country look. Global marketing is the buzzword phrase these days, and the industries that put their products into aerosols are no exception. Their business is becoming more international. That internationalization is good news for the aerosol industry as it marches back into good health. ◻

Survey data probe status of chemists

The chemical profession in the U.S. is dominated by white males. In 1985, more than three fourths of the members of the American Chemical Society fit that description.

Consequently, any broad demographic look at working chemists is likely to be skewed to reflect the characteristics of that single dominant mass, one in which the traits of all the many smaller groups, such as Asians or blacks—or even women—may be largely buried.

Last year's annual survey of employment and salaries among members of ACS, however, has provided an unprecedented opportunity to gauge the economic status of groups of chemists who are too few in number to have been represented adequately in earlier surveys.

The 1985 ACS survey differed from previous surveys in that it targeted all members living in the U.S. who were under 70 years of age and neither retired nor students, rather than just a random sampling of such members. Response to the survey was about 50%, so that data were obtained from nearly 44,000 members, three to four times more than responded to other recent surveys. As a result, usable information is available for the first time from several groups of chemists from whom responses previously had been relatively sparse.

In addition, the more detailed information than usual that has been garnered from the 1985 survey regarding the status of women chemists can be compared with results from two earlier surveys, in 1975 and 1980, that covered all female ACS members in the U.S. work force.

Speakers at the Division of Professional Relations' symposium on the "Status of the Chemist in 1985" evaluated this wealth of new information. So also does the report "Women Chemists 1985" just published by the ACS Office of Statistical Services.

Data compiled in "Women Chemists 1985" show that women comprise an increasingly larger fraction of the total chemical profession. Last year, about 15% of ACS members working in the U.S. were women, up from 10% in 1980 and less than 8% in 1975.

Women chemists tend to be markedly younger (and consequently less experienced) than their male colleagues, the report also shows. This is due, in large part, to the increasing share of degrees in chemistry that is being earned by women, especially at the B.S. level. Recently, a third of B.S. chemistry degrees awarded in the U.S. went to women, compared with less than 20% 15 to 20 years ago. One result is that half of women chemists whose highest degree is a B.S. are under 30 years old, but only 21% of the men with a B.S. are that young.

In general, the differences in salaries earned by men and women chemists working in industry or government have narrowed during the past decade, especially for young workers. Even so, men still hold an overall advantage. One reason is that women, perhaps as a reflection of their relative youth, are less apt to hold management positions. For instance, although only 16% of the men with Ph.D.s working in industry have no subordinate, 45% of the women have none.

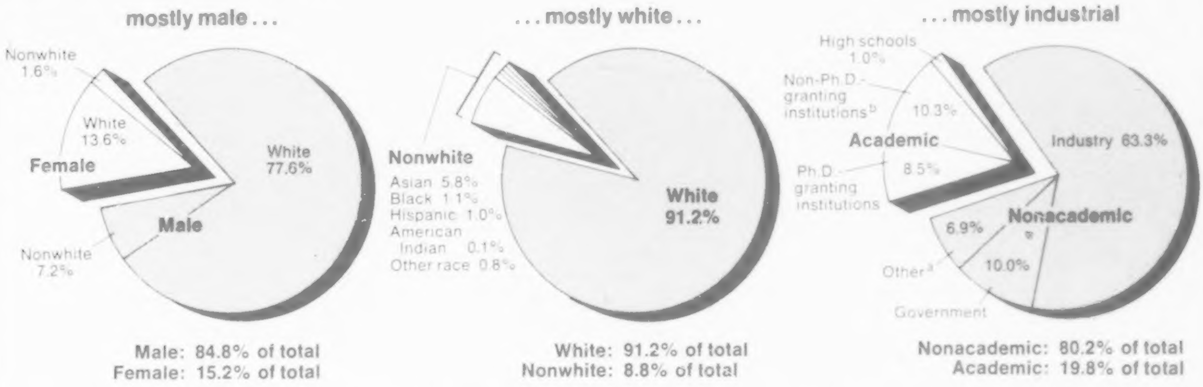
Another factor is the areas in which women tend to work. As Polly Phipps of the University of Michigan pointed out during the Division of Professional Relations symposium, although an increasing number of women are now being attracted to chemical careers, they tend to move into fields where salaries are lowest. The two highest-paying fields of specialization for chemists are physical and polymer chemistry, for example; in both of these women are underrepresented. On the other hand, in biochemistry, pharmaceutical chemistry, and analytical chemistry, which are among the lowest-paying specialties, women are overrepresented. Similarly, salaries tend to be highest for chemists employed by oil, chemical, paper, or rubber firms, industries in which women also are underrepresented. And they tend to be low for chemists working for hospitals and independent labs or for state and local government agencies, for which the number of women employed is greater than average.

Although the percentage has been declining, women chemists with a Ph.D. are more likely to be working in universities and colleges than anywhere else. Last year, 46% of Ph.D. women worked for such institutions, compared with 34% of men with Ph.D.s. The salaries of women in academia have increased during the past 10 years relative to the salaries earned by their male counterparts, according to Margaret A. Cavanaugh of Saint Mary's College in Notre Dame, Ind. Cavanaugh finds, nonetheless, that women's salaries still slightly lag those of men in schools that do not have Ph.D. programs. And in the more prestigious institutions that award the Ph.D., the differences between men's and women's salaries can be greater still.

The 1985 ACS survey asked several questions to probe how well chemists like their work and how they view their career prospects. Generally speaking, Terrence R. Russell of the ACS Department of Professional Services finds, younger women are more satisfied with their jobs than older women are; however, the reverse is true for men. Russell hypothesizes that this is the case because younger people are more likely to compare themselves with people of similar age and sex in other professions rather than with other chemists. Thus, young women chemists tend to compare their salaries with young women in such low-paying professions as teaching or nursing, whereas young men chemists match their earnings against the income of young doctors or lawyers.

Black chemists are another group for which job conditions seem to have improved. Slightly more than 1% of native-born U.S. chemists are

U.S. working chemists are



a Includes hospitals, independent laboratories, nonprofit organizations, and self-employed. **b** Includes medical and professional schools. **Source:** ACS survey, 1985

black, the ACS survey indicated, in an overall U.S. population that is 12% black. They are much more likely to be women (27% are of that sex) than is the case with whites. On the other hand, their age distribution is very similar to that of whites. This suggests to sociologists Jerry Gaston of Texas A&M University and Willie Pearson Jr. of Wake Forest University that recruitment of blacks into chemistry, relative to whites, has not increased in recent years.

In analyzing salary data for black and white chemists, Gaston and Pearson conclude that at least among younger chemists the "disparity between blacks and whites has been reduced almost to the point of equality." That is, for blacks and whites of the same sex, the percentage earning above or below the average level is nearly the same if they have earned their B.S. degree in the past 20 years. This indicates considerable progress, Gaston and Pearson say, if the data are compared with those for chemists who obtained their B.S. in 1955 or before, a group in which most of the above-average salaries go to white males.

Accounting for almost 6% of ACS members working in the U.S., chemists of Asian background constitute the second largest ethnic group by a wide margin. The proportion of Asians in the chemical profession is roughly half again as big as it was 10 years ago, and it is much higher than 1.6% of the total U.S. population that was Asian at the time of the 1980 census.

A perhaps surprising 84% of Asian chemists are immigrants, according to statistics worked up by Robert Jones and Sovan Tun of the ACS statistical services office. But just over half of the total are naturalized U.S. citizens now, and another fourth, although noncitizens, hold permanent resident status. Japanese chemists, who account for 12% of all Asians, are the only exception; almost 75% of them are natives of the U.S. In contrast, of the 45% of Asian chemists who are Chinese, only 13% were born in the U.S., and practically all the Indian chemists (22% of the Asian total) were born in India.

Perhaps because, as immigrants, they need an advanced degree to compete in a foreign job market, a surprising number of Asian chemists in the U.S. have Ph.D.s. For instance, 83% of those from India and about 75% of Chinese and Korean chemists have earned a doctorate, compared to only slightly more than half of white chemists.

Chemists doing part-time work are another relatively small part of ACS membership—just over 2% of the total—but they make up a group whose characteristics are quite distinct, as well. Although more men than women work part time, the proportion of all women chemists with part-time jobs is much higher (5% compared with less than 2% among men). Thus a woman is twice as likely as a man to be working less than full time. These women, moreover, most likely hold academic jobs. According to Kathleen Trahanovsky of Iowa State University, 9% of the women employed in academic institutions work part time, and although women hold only 16% of all academic positions in chemistry, they account for 52% of all academic chemists who work part time.

Part-time chemists working outside academia tend to be older than those in full-time jobs; more than 30% are over 60, compared with less than 10% of all nonacademic chemists. They also are likely to be self-employed—18% are, compared with just 1% of all nonacademic chemists—and to be doing consulting (27%, compared with only 2% of all nonacademic chemists).

Nearly 40% of the men working part time do so because they prefer to, Trahanovsky finds; another third work part time because they have been unable to find full-time jobs. For women, on the other hand, the biggest reason for part-time work—cited by about a third—is marriage or family constraints. Only 60% of all women chemist surveyed last year were married, but of those employed part time, 83% were married.

As a sidelight, the 1985 ACS survey found that among the 60% of presently married women chemists, 30% are married to another chemist and nearly as many to some other type of scientist. On the other hand, of the 83% of surveyed men chemists who are married, only 20% are married to a scientist of any type and slightly less than half of these are married to a chemist. □

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Top 100 Chemical Producers: 1985 Sales, Profits Decline for Most

Of 100 largest companies, 54 reported lower sales, 50 lower operating profits from chemicals last year compared with 1984

William J. Storck, David Webber
C&EN New York

The all-but-moribund agriculture business and shrinking oil prices helped keep sales volume down and the marketplace resistant to chemical product price increases last year. With those and other factors offsetting improvements in other sectors of the economy, sales and operating profits from chemical operations at the 100 biggest chemical producers mostly declined in 1985.

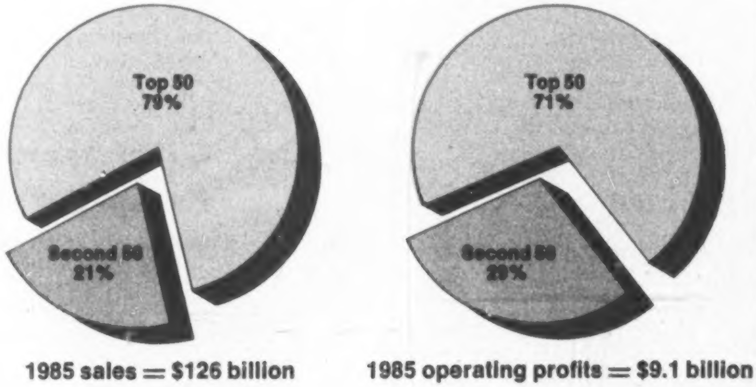
Of the 50 largest members of C&EN's list of the Top 100 chemical producers, 30 recorded lower chemical sales and 33 lower chemical operating profits as a percentage of total operating profits in 1985 compared with 1984. In the group comprising the smaller 50 chemical producers on the list, 24 reported a decline in chemical sales and 23 had a drop in chemical operating profits as a share of total operating profits. Chemical operating profit is calculated by subtracting administrative expenses and cost of sales from chemical sales.

Despite some trading of places, the same companies comprised the top 10 members of the list in terms of chemical sales in 1985 as in 1984. Du Pont continued to head the list, although its lead over second-place Dow Chemical shrank considerably. In 1985, Du Pont's chemical sales dropped 6.3%, and Dow's fell just 0.9%. On the other hand, Du Pont's chemical operating profit, down 21.4% from 1984's $1.11 billion, declined less than did Dow's, down 44.5% from the previous year's $741 million.

Atlantic Richfield moved up to sixth place from eighth on the list at the expense of Shell Oil, which dropped a notch to seventh, and Celanese, which also moved down a notch to eighth in terms of chemical sales. Amoco and W. R. Grace traded places on the list, with Amoco rising to ninth while Grace subsided to 10th.

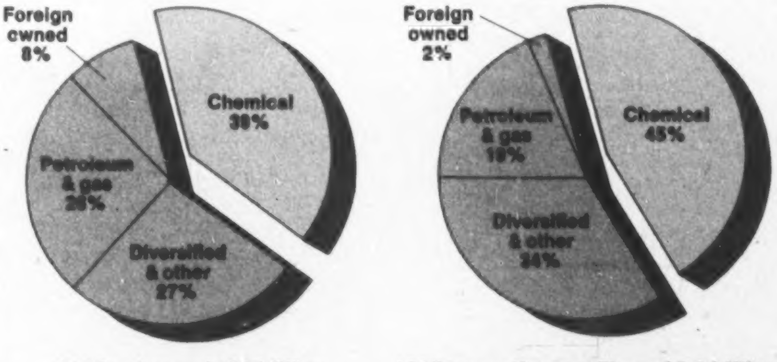
A number of new entries appear on this year's Top 100 list of chemical producers. Chesebrough-Pond's, for instance, became a chemical producer for the first time last year with its acquisition of Stauffer Chemical. The company joins the ranking in 35th place. In 1984, Stauffer, which has suffered greatly from the agriculture slump, was ranked 22nd. Among other new qualifiers for the list in 1985 are Vista Chemicals, 61st in size, formed by the leveraged buyout of the

Large firms dominate sales, to lesser extent earnings . . .



1985 sales = $126 billion   1985 operating profits = $9.1 billion

. . . and chemical firms prevail among types of companies



1985 sales = $126 billion   1985 operating profits = $9.1 billion

Restructuring, mergers changed many rankings in 1985

Rank 1985	Rank 1984		Chemical sales 1985 ($ millions)	Change from 1984	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1984	Chemical operating profits as % of total operating profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$11,250	−6.3%	38.2%	Diversified	$870	−21.4%	22.0%	7.7%	$7885	34.3%	11.0%
2	2	**Dow Chemical**	9,508	−0.9	62.4	Basic chemicals	411	−44.5	64.5	4.3	8047	68.0	5.1
3	3	**Exxon**	6,670	−2.9	7.3	Petroleum	385	−43.1	3.5	5.8	5337	7.7	7.2
4	4	**Monsanto**	5,203[d]	−12.6	77.1	Basic chemicals	477	−26.7	135.9	9.2	4217	47.5	11.3
5	5	**Union Carbide**	3,961	−4.7	44.0	Basic chemicals	413	−14.0	50.0	10.4	4330	44.7	9.5
6	8	**Atlantic Richfield**	3,804	21.0	16.9	Petroleum	73[e]	−49.3	4.9	1.9	2296	11.3	3.2
7	6	**Shell Oil**	3,318	−1.9	16.3	Petroleum	165	−39.6	5.2	5.0	3891	14.7	4.2
8	7	**Celanese**	3.046	−6.5	100.0	Basic chemicals	127	−53.3	100.0	4.2	2809	100.0	4.5
9	10	**Amoco**	2,905	2.5	10.1	Petroleum	473	35.5	11.5	16.3	2334	9.3	20.3
10	9	**W. R. Grace**	2,868	0.7	39.5	Specialty chemicals	234	−30.8	58.4	8.2	1997	36.8	11.7
11	34	**Chevron**	2,611	137.4	6.0	Petroleum	−163	def	def	def	3010	7.7	def
12	32	**BASF**	2,600[d]	14.0	100.0	Basic chemicals	na	na	na	na	na	na	na
13	11	**Eastman Kodak**	2,348	−4.7	22.1	Photo equipment	183	−34.9	32.6	7.8	2136	17.6	8.6
14	15	**General Electric**	2,347	10.9	8.0	Electrical products	466	−0.9	13.2	19.9	3876	14.7	12.0
15	13	**Phillips Petroleum**	2,266	−3.6	14.5	Petroleum	219	−0.9	8.0	9.7	1315	9.4	16.7
15	14	**Mobil**	2,266	−3.6	3.7	Petroleum	81	42.1	1.3	3.6	2045	4.9	4.0
17	12	**Allied-Signal**	2,055	−15.5	22.5	Diversified	195	−15.6	21.8	9.5	1979	14.9	9.9
18	16	**Rohm & Haas**	1,968	0.2	95.9	Basic chemicals	270	−18.9	99.3	13.7	1381	98.9	19.6
19	17	**American Cyanamid**	1,830	−3.6	51.8	Basic chemicals	81	−40.2	32.1	4.4	1254	54.6	6.4
20	18	**Hercules**	1,743	−4.4	67.8	Basic chemicals	47	−63.6	35.9	2.7	1409	53.0	3.3
21	19	**Air Products**[f]	1,674	4.4	91.5	Basic chemicals	312	6.9	114.3	18.6	1937	74.7	16.1
22	37	**Occidental Petroleum**	1,621[g]	64.6	10.4	Petroleum	100	45.4	5.5	6.2	1721	14.9	5.8
23	24	**Mobay**	1,599	3.0	100.0	Basic chemicals	150	11.2	100.0	9.4	1215	100.0	12.4
24	20	**Ciba-Geigy**	1,540	−1.3	64.2	Specialty chemicals	na	na	na	na	na	na	na
25	26	**Borden**	1,532	5.8	32.5	Dairy products	129	−24.1	32.4	8.4	1336	47.4	9.6
26	23	**Ashland Oil**	1,499	−0.1	18.3	Petroleum	68	23.6	19.3	4.5	496	12.6	13.7
27	27	**B. F. Goodrich**	1,384	−2.8	43.2	Rubber products	79	−30.4	51.1	5.7	1154	51.1	6.9
28	25	**American Hoechst**	1,361[d]	−7.3	80.4	Basic chemicals	na	na	na	na	na	na	na
29	31	**FMC**	1,261	2.0	38.7	Machinery	143	−23.5	53.2	11.4	1260	46.8	11.4
30	28	**Ethyl**	1,242	−9.0	60.3	Basic chemicals	198	4.2	84.3	16.0	768	49.4	25.8
31	21	**Texaco**	1,220	−20.7	2.6	Petroleum	12	−60.2	0.3	1.0	1010	2.7	1.2
32	28	**U.S. Steel**	1,217	−9.7	6.3	Steel	−1	def	def	def	587	3.2	def
32	30	**Unocal**	1,217	−2.6	10.8	Petroleum	58[e]	−33.3	17.6	4.8	772	7.2	7.5
34	33	**Olin**	1,147	−2.3	65.5	Basic chemicals	46	−24.5	44.3	4.0	825	51.6	5.6
35	—	**Chesebrough-Pond's**	1,079	nm	40.0	Diversified	60	nm	27.7	5.6	1771	58.9	3.4
36	38	**International Minerals**[h]	1,057	8.1	61.2	Agrichemicals	135	−7.7	62.8	12.7	1285	65.6	10.5
37	42	**National Distillers**	1,037	−4.0	45.3	Alcoholic beverages	72	−29.6	37.7	6.9	746	36.9	9.6
38	39	**Borg-Warner**	929	−1.6	27.9	Auto equipment	122	0.8	35.8	13.2	437	15.5	28.0
39	40	**CF Industries**	921[d]	1.4	100.0	Agrichemicals	−1	def	def	def	936	100.0	def
40	42	**Dow Corning**	901	5.4	100.0	Specialty chemicals	95[e]	4.3	100.0	10.6	na	na	na
41	57	**National Starch**	881	nm	100.0	Specialty chemicals	66	20.0	100.0	7.5	655	100.0	10.1
42	36	**PPG Industries**	841	−15.3	19.4	Glass products	80	−34.0	17.9	9.5	1129	27.6	7.1
43	46	**Reichhold Chemicals**	823	2.6	100.0	Basic chemicals	21	−51.6	100.0	2.6	492	100.0	4.3
44	43	**Lubrizol**	804	−3.4	89.0	Specialty chemicals	93	−8.4	97.5	11.6	603	70.6	15.5
45	44	**Williams Cos.**	742	−10.7	23.6	Agrichemicals	−16	def	def	def	553	12.8	def
46	45	**Diamond Shamrock**	736	−10.3	17.9	Petroleum	121	4.1	33.9	16.5	791	17.1	15.3
47	47	**Farmland Industries**	721	−8.0	24.2	Agricultural supplies	3	−91.5	3.8	0.4	407	31.7	0.7
48	48	**Eli Lilly**	713	−5.8	21.8	Drugs	88	−18.4	10.7	12.4	812	20.5	10.9
48	59	**Cabot**[e]	712	31.4	50.6	Specialty metals	88	31.8	43.5	12.4	482	30.2	18.3
50	52	**Nalco Chemical**	682	2.7	100.0	Specialty chemicals	122	5.6	100.0	17.5	542	100.0	22.4

Rank 1985	Rank 1984		Chemical sales 1985 ($ millions)	Change from 1984	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1984	Chemical operating profits as % of total operating profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	53	**Pennwalt**	$680	3.8%	67.1%	Basic chemicals	$ 59	13.9%	72.3%	8.7%	$612	63.9%	9.7%
52	41	**Koppers**	619	−30.1	44.2	Diversified	−62	def	def	def	373	35.0	def
53	54	**Morton Thiokol**[h]	616	−5.8	33.8	Diversified	90	10.7	37.6	14.6	543	39.7	16.5
54	58	**Engelhard**	598	8.8	26.4	Specialty metals	62	−6.1	72.9	10.4	528	56.4	11.7
55	70	**Enron**	581	46.8	5.7	Natural gas	34	−26.6	5.5	5.9	590	6.0	5.8
56	72	**Terra Chemicals**	574	55.1	100.0	Agrichemicals	na	na	na	na	na	na	na
56	56	**Witco**	574	−7.9	39.6	Specialty chemicals	57	−12.6	49.5	9.9	265	32.7	21.4
58	63	**NL Industries**	564	19.3	39.6	Petroleum services	127	33.9	105.8	22.5	397	24.9	32.0
59	50	**Standard Oil (Ohio)**	552	−21.9	4.0	Petroleum	27	−38.6	0.9	4.9	549	3.0	4.9
60	74	**SCM**[h]	539[d]	48.4	24.8	Paint	74	99.8	59.5	13.7	483	35.5	15.3
61	—	**Vista Chemicals**[e]	521	nm	100.0	Basic chemicals	na	na	na	na	na	na	na
62	76	**Solvay America**	515	nm	100.0	Basic chemicals	na	na	na	na	na	na	na
63	64	**Polysar**	513	16.6	100.0	Basic chemicals	na	na	na	na	na	na	na
64	62	**International Flavors**	501	5.1	100.0	Specialty chemicals	118	1.5	100.0	23.5	560	100.0	21.0
65	60	**Kerr-McGee**	483	−7.1	14.4	Petroleum	47	def	11.9	9.7	567	15.3	8.3
66	68	**Liquid Air**	459	7.8	84.6	Basic chemicals	58	10.7	94.0	12.6	na	na	na
67	65	**H. B. Fuller**[i]	457	2.4	100.0	Specialty chemicals	31	−4.5	100.0	6.7	246	100.0	12.5
68	61	**Freeport-McMoRan**	451	−8.5	62.5	Agrichemicals	105	−4.5	70.3	23.3	215	10.5	48.8
69	55	**Merck**	450	−29.8	12.7	Drugs	58	−25.4	6.8	13.0	369	7.5	15.8
70	79	**Big Three Industries**	411	21.1	49.3	Petroleum services	104	38.3	75.8	25.4	594	55.6	17.6
71	81	**American Petrofina**	405	27.3	16.8	Petroleum	12	−42.1	def	2.9	314	17.9	3.7
72	69	**Sun Co.**	402	−4.8	2.8	Petroleum	na	na	na	na	na	na	na
73	72	**Rhône-Poulenc**	400	8.1	100.0	Specialty chemicals	na	na	na	na	na	na	na
74	71	**Pfizer**	392	6.6	9.7	Drugs	17	280.0	1.8	4.4	400	9.0	4.3
75	78	**Tyler**	375	8.4	41.1	Diversified chemicals	30	−61.5	0.1	7.9	174	36.7	17.0
76	75	**GAF**	364	2.0	49.8	Specialty chemicals	93	17.2	81.4	25.4	217	24.7	42.6
77	81	**Chemed**	336	5.9	90.3	Specialty chemicals	43	3.8	88.6	12.8	159	69.3	27.1
78	77	**Mississippi Chemical**	325	−6.8	100.0	Farm cooperative	3	−32.3	100.0	0.9	320	100.0	0.9
79	83	**Betz Laboratories**	319	5.1	100.0	Specialty chemicals	61	0.3	100.0	19.0	254	100.0	23.9
80	84	**Vulcan Materials**	292	−3.2	30.1	Nonmetallic minerals	24	−48.4	18.8	8.3	na	na	na
81	85	**Petrolite**[j]	290	2.1	93.9	Specialty chemicals	36	−11.0	106.1	12.4	170	74.4	21.2
82	—	**Dexter**	281	−2.1	44.4	Specialty materials	28	−8.7	42.2	10.0	150	30.9	18.9
83	86	**Great Lakes Chemical**	277	−0.5	100.0	Specialty chemicals	45	−19.8	100.0	16.4	na	na	na
84	—	**Union Camp**	275	−7.0	14.7	Wood products	9	−56.4	7.2	3.2	207	7.8	4.3
84	87	**Aluminum Co. of America**	271	−0.7	5.3	Nonferrous metals	na	na	na	na	na	na	na
86	87	**Ferro**	267[d]	−1.9	41.1	Specialty materials	14	−14.4	37.0	5.1	143	36.4	9.6
87	90	**Emhart**	257	−1.6	14.5	Machinery	19	−17.4	10.6	7.4	132	8.6	14.4
88	91	**Kaiser Aluminum**	255	2.3	12.6	Nonferrous metals	8	−80.0	def	3.1	275	8.4	2.8
89	93	**Stepan**	236	0.4	100.0	Specialty chemicals	9	51.3	100.0	3.9	139	100.0	6.6
90	92	**Loctite**	231	−4.2	100.0	Specialty chemicals	35	−18.0	100.0	15.1	219	100.0	15.9
91	—	**Lonza**	197	9.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
92	66	**Georgia-Pacific**	173	−61.2	3.9	Wood products	na	na	na	na	na	na	na
93	95	**Essex Chemical**	172	−2.2	90.6	Basic chemicals	32	18.5	118.5	18.6	94	66.7	33.9
94	—	**Millmaster Onyx**	170	0.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
95	99	**Sigma-Aldrich**	165	19.4	76.7	Specialty chemicals	47	21.0	89.3	28.6	157	84.1	30.1
96	96	**Agway**	162	−2.7	4.0	Farm cooperative	na	na	na	na	na	na	na
97	97	**First Mississippi**	151	−8.6	55.2	Agrichemicals	31	11.0	81.4	20.6	68	17.3	45.4
98	—	**UGI**	117	3.5	19.4	Natural gas	0	−90.0	def	0.1	133	21.4	0.1
99	100	**Crompton & Knowles**	113	−2.1	48.7	Specialty chemicals	12	−8.2	58.6	11.0	73	55.8	17.2
100	—	**Lawter Chemicals**	97	−1.7	100.0	Specialty chemicals	13	−38.1	100.0	13.7	84	100.0	15.7

a Operating profit is sales less administrative expenses and cost of sales. b Operating profit from chemicals as a percentage of chemical sales. c Chemical operating profit as a percentage of identifiable chemical assets. d Chemical sales include significant amounts of nonchemical products. e Chemical net profits. f Fiscal year ended Sept. 30. g Does not include all chemical sales. h Fiscal year ends June 30. i Fiscal year ends Nov. 30. j Fiscal year ends Oct. 31. na = not available. nm = not meaningful. def = deficit.

C&EN's five-way ranking of the Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1985	1985	1984	1985	1985	1984	1985	1985	1984	1985	1985	1984	1985	1985	1984
Agway	$ 162	96	96	na	—	—	na	—	—	na	—	—	na	—	—
Air Products	1,674	21	19	$ 312	8	10	18.6%	10	12	$1937	16	14	16.1%	24	26
Allied-Signal	2,055	17	13	195	13	14	9.5	39	47	1979	15	18	9.9	44	25
Aluminum Co. of America	271	85	87	na	—	—	na	—	—	na	—	—	na	—	—
American Cyanamid	1,830	19	17	81	34	21	4.4	64	60	1254	25	23	6.4	57	51
American Hoechst	1,361	28	25	na	—	—	na	—	—	na	—	—	na	—	—
American Petrofina	405	71	81	12	71	73	2.9	73	63	314	61	60	3.7	69	67
Amoco	2,905	9	10	473	3	7	16.3	15	30	2334	70	11	20.3	15	29
Ashland Oil	1,499	26	23	66	40	50	4.5	63	75	496	50	46	13.7	32	49
Atlantic Richfield	3,804	6	8	na	—	19	na	—	71	2296	11	8	na	—	71
BASF	2,600	12	32	na	—	66	na	—	76	na	—	—	na	—	—
Betz Laboratories	319	79	83	61	43	46	19.0	9	10	254	64	65	23.9	10	8
Big Three Industries	411	70	79	104	27	39	25.4	2	4	594	40	44	17.6	19	41
Borden	1,532	25	26	129	19	18	8.4	44	40	1336	21	19	9.6	46	42
Borg-Warner	929	38	39	122	22	25	13.2	22	27	437	54	54	28.0	7	5
CF Industries	921	39	40	−1	80	51	def	—	66	936	30	26	def	—	70
Cabot	712	49	59	88	32	42	12.4	27	28	482	52	63	18.3	18	13
Celanese	3,046	8	7	127	20	13	4.2	67	53	2809	9	7	4.5	63	58
Chemed	336	77	81	43	55	59	12.8	24	26	159	72	77	27.1	6	7
Chesebrough-Pond's	1,079	35	—	60	44	—	5.6	58	—	1771	17	—	3.4	70	—
Chevron	2,611	11	34	−163	84	—	def	—	—	3010	8	31	def	—	—
Ciba-Geigy	1,540	24	20	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	113	99	100	12	71	78	11.0	32	37	73	81	85	17.2	20	19
Dexter	281	82	—	28	63	—	10.0	35	—	150	74	—	18.9	17	—
Diamond Shamrock	736	46	45	121	24	26	16.5	13	22	791	33	34	15.3	29	30
Dow Chemical	9,508	2	2	411	6	2	4.3	66	56	8047	1	1	5.1	61	55
Dow Corning	901	40	42	na	—	—	na	—	—	na	—	—	na	—	—
Du Pont	11,250	1	1	870	1	1	7.7	49	50	7885	2	2	11.0	40	33
Eastman Kodak	2,348	13	12	183	14	11	7.8	48	42	2136	12	12	8.6	50	38
Eli Lilly	713	48	48	88	32	32	12.4	27	22	812	32	33	10.9	41	36
Emhart	257	87	90	19	67	72	7.4	51	51	132	78	83	14.4	31	18
Engelhard	598	54	58	62	42	43	10.4	33	37	528	49	52	11.7	36	31
Enron	581	55	70	34	58	54	5.9	55	36	590	41	39	5.8	58	62
Essex Chemical	172	93	95	32	59	70	18.6	10	18	94	79	83	33.9	4	13
Ethyl	1,242	30	28	198	12	16	16.0	16	25	768	35	32	25.8	9	15
Exxon	6,670	3	3	385	7	3	5.8	56	46	5337	3	3	7.2	53	43
FMC	1,261	29	31	143	17	17	11.4	31	19	1260	24	29	11.4	38	22
Farmland Industries	721	47	47	3	77	67	0.4	78	74	407	55	50	0.7	75	65
Ferro	267	86	87	14	69	76	5.1	59	67	143	75	79	9.6	46	47
First Mississippi	151	97	97	31	60	69	20.6	7	13	68	82	85	45.4	2	4
Freeport-McMoRan	451	68	61	105	26	30	23.3	5	3	215	68	69	48.8	1	1
H. B. Fuller	457	67	65	31	60	67	6.7	53	59	246	65	67	12.5	33	35
GAF	364	76	75	93	29	37	25.4	2	7	217	67	70	42.6	3	3
General Electric	2,347	14	15	466	4	6	19.9	8	6	3876	7	9	12.0	35	20
Georgia-Pacific	173	92	66	na	—	87	na	—	—	na	—	75	na	—	—
B. F. Goodrich	1,384	27	27	79	37	29	5.7	57	56	1154	27	17	6.9	55	59
W. R. Grace	2,868	10	9	234	10	8	8.2	46	37	1997	14	13	11.7	36	21
Great Lakes Chemical	277	83	86	45	54	49	16.4	14	8	na	—	61	na	—	20
Hercules	1,743	20	18	47	50	22	2.7	74	60	1409	19	20	3.3	71	56
International Flavors	501	64	62	118	25	26	23.5	4	2	560	44	55	21.0	14	11

$ Millions	Chemical sales 1985	Chemical sales Rank 1985	Chemical sales Rank 1984	Chemical operating profits 1985	Chemical operating profits Rank 1985	Chemical operating profits Rank 1984	Chemical operating profit margin 1985	Chemical operating profit margin Rank 1985	Chemical operating profit margin Rank 1984	Identifiable chemical assets 1985	Identifiable chemical assets Rank 1985	Identifiable chemical assets Rank 1984	Return on chemical assets 1985	Return on chemical assets Rank 1985	Return on chemical assets Rank 1984
International Minerals	$1,057	36	38	$135	18	20	12.7%	25	20	$1285	23	21	10.5%	42	48
Kaiser Aluminum	255	88	91	8	76	61	3.1	72	18	275	62	63	2.8	72	37
Kerr-McGee	483	65	60	47	50	86	9.7	37	—	567	43	42	8.3	51	—
Koppers	619	52	41	−62	83	74	def	—	81	373	58	49	def	—	75
Lawter International	97	100	—	13	70	—	13.7	19	—	84	80	—	15.7	27	—
Liquid Air	459	66	68	58	46	52	12.6	26	34	na	—	—	na	—	—
Loctite	231	90	92	35	57	58	15.1	17	11	219	66	66	15.9	25	23
Lonza	197	91	—	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	604	44	43	93	29	33	11.6	30	30	603	39	37	15.5	28	34
Merck	450	69	55	58	46	38	13.0	23	34	369	59	41	15.8	26	41
Millmaster Onyx	170	94	—	na	—	—	na	—	—	na	—	—	na	—	—
Mississippi Chemical	325	78	77	3	77	83	0.9	77	82	320	60	57	0.9	74	79
Mobay	1,599	23	24	150	16	—	9.4	41	—	1215	26	—	12.4	34	—
Mobil	2,266	15	11	81	34	47	3.6	70	79	2045	13	10	4.0	68	78
Monsanto	5,203	4	4	477	2	4	9.2	42	43	4217	5	4	11.3	39	40
Morton Thiokol	616	53	54	90	31	36	14.6	18	28	543	47	47	16.5	23	27
NL Industries	564	58	63	127	20	35	22.5	6	9	397	57	62	32.0	5	5
Nalco Chemical	682	50	52	122	22	28	17.8	12	12	542	48	48	22.4	11	15
National Distillers	1,037	37	35	72	39	33	6.9	52	48	746	36	35	9.6	48	39
National Starch	861	41	57	66	41	—	7.5	50	—	655	37	—	10.1	43	—
Occidental Petroleum	1,621	22	37	100	28	40	6.2	54	62	1721	18	28	5.8	58	66
Olin	1,147	34	33	46	53	45	4.0	68	70	825	31	25	5.6	60	70
PPG Industries	841	42	36	80	36	24	9.5	39	30	1129	28	24	7.1	54	51
Pennwalt	680	51	53	59	45	52	8.7	43	57	612	38	45	9.7	46	53
Petrolite	290	81	85	36	56	60	12.4	27	22	170	71	73	21.2	13	14
Pfizer	392	74	71	17	68	82	4.4	64	82	400	56	53	4.3	64	80
Phillips Petroleum	2,266	15	14	219	11	15	9.7	37	48	1315	22	16	16.7	22	32
Polysar	513	63	64	na	—	—	na	—	—	na	—	—	na	—	—
Reichhold Chemicals	823	43	46	21	66	56	2.6	75	69	492	51	56	4.3	64	45
Rhône-Poulenc	400	73	72	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	1,966	18	18	270	9	9	13.7	19	14	1381	20	22	19.6	16	10
SCM	539	60	74	74	38	64	13.7	19	45	483	52	59	15.3	29	48
Shell Oil	3,318	7	6	165	15	12	5.0	60	55	3891	6	6	4.2	67	61
Sigma-Aldrich	165	95	99	47	50	63	28.6	1	1	157	73	72	30.1	6	9
Solvay America	515	62	76	na	—	—	na	—	—	na	—	—	na	—	—
Standard Oil (Ohio)	552	59	50	27	64	56	4.9	61	64	549	46	38	4.9	62	67
Stepan	236	89	93	9	74	81	3.9	69	77	139	76	80	6.6	56	73
Sun Co.	402	72	69	na	—	—	na	—	—	na	—	—	na	—	—
Terra Chemicals	574	56	72	na	—	—	na	—	—	na	—	—	na	—	—
Texaco	1,220	31	21	12	71	61	1.0	76	78	1010	29	27	1.2	73	76
Tyler	375	75	78	30	62	80	7.9	47	79	174	70	74	17.0	21	2
U.S. Steel	1,217	32	28	−1	80	47	def	—	84	587	42	40	def	—	57
UGI	117	98	—	0	79	—	0.1	79	—	133	77	—	0.1	76	—
Union Camp	275	84	—	9	74	—	3.2	71	—	207	69	—	4.3	64	—
Union Carbide	3,961	5	5	413	5	5	10.4	33	41	4330	4	5	9.5	49	53
Unocal	1,217	32	30	58	46	—	4.8	62	—	772	34	36	7.5	52	—
Vista Chemical	521	61	—	na	—	—	na	—	—	na	—	—	na	—	—
Vulcan Materials	292	80	84	24	65	54	8.3	45	16	na	—	—	na	—	—
Williams Cos.	742	45	44	−16	82	41	def	—	53	553	45	30	def	—	64
Witco	574	56	58	57	49	44	9.9	36	44	265	63	65	21.4	12	18

Note: Companies with negative profitability and those giving only net profits are not ranked. There are 84 companies ranked for operating profit, 79 for operating profit margin, 82 ranked by assets, and 76 ranked for return on assets. Companies not included in 1984's listing are not ranked for that year. **na** = not available. **def** = deficit.

Smaller producers fare better than do larger firms

Ending a period of two consecutive years in which the 50 largest companies among C&EN's Top 100 chemical producers outperformed the 50 smaller firms, the group of smaller companies did better in 1985.

Last year's economic problems afflicted the 50 largest firms more severely, because those companies are largely makers of cyclical, large-volume commodity chemicals. The Second 50 chemical producers, on the other hand, are mainly manufacturers of chemical specialties.

As a result, composite chemical sales by the Top 50 group declined to about $107 billion in 1985, down 0.4% from 1984. By comparison, composite chemical sales for the Second 50 rose to $1.8 billion, up 3.9% from the 1984 aggregate total. For the entire Top 100 chemical producers roster, chemical sales in 1985 amounted to $125 billion, up a scant 0.2% from the composite total for 1984.

The Second 50 group's composite chemical operating profits did decline in 1985, but by much less than did those for the Top 50 companies. For the largest producers, composite chemical operating profits tumbled 24% to $7.4 billion last year. For the smaller producers, chemical operating profits fell to $1.6 billion, down a little more than 4% from their total in 1984. For the Top 100, composite chemical operating profits came to $9 billion, down a substantial 21% from the year before.

At the same time, total identifiable chemical assets increased in all three company categories. For the Top 50 companies, the value of chemical assets climbed 6% from 1984 to $84.5 billion. The Second 50 group added $10.8 billion to its base of identifiable chemical assets. This was a 2.8% increase from 1984. And for the entire Top 100 list of chemical producers, identifiable chemical assets increased 5.6% to a composite $95.3 billion.

	Top 50		Second 50		Total 100	
$ Billions	1985	% change	1985	% change	1985	% change
Chemical sales	$106.6	−0.4%	$ 1.8	3.9%	$125.0	0.2%
Chemical operating profits	7.4	−23.9	1.6	−4.3	9.0	−21.0
Chemical assets	84.5	6.0	10.8	2.8	95.3	5.6

Note: Excludes companies lacking comparative data.

chemical operations of Du Pont's Conoco unit; Lonza, 91st in size; Millmaster Onyx, 94th on the list; and Lawter Chemicals, 100th.

Two other firms, which qualified to appear in the 1984 ranking but were not listed because data were lacking at the time of publication, now join the list. They are Betz Laboratories, ranked 79th, and Sigma-Aldrich, ranked 95th. Although those companies were not included in last year's Top 100 list (C&EN, May 6, 1985, page 15), they were included in a revised list in C&EN's Facts & Figures of the Chemical Industry issue (C&EN, June 10, 1985, page 22).

Dropped from the list this year are Uniroyal, which was taken private in a leveraged buyout during 1985 and no longer reports consistent data; Avon Products, which sold its Mallinckrodt division (Avon's only chemical operation) to International Minerals & Chemical; and Sterling Drug, which has changed its method of accounting and no longer breaks out chemical data.

As usual, a number of companies with large chemical segments do not appear on the list because they fail to disclose chemical data. Prominent among such chemical producers are ICI Americas and Procter & Gamble.

As in last year's Top 100 report, except where there were massive reorganizations, companies in the 1985 ranking are compared with their rankings of a year ago, instead of rankings based on restated results in the current annual report. Thus, a rise or fall in rank may well reflect acquired or divested chemical businesses as well as increasing or decreasing sales from operations.

C&EN ranks the Top 100 chemical producers five ways. Du Pont, the leader in terms of chemical sales, is also the leader in terms of chemical operating profits. The company with the second highest chemical sales is Dow Chemical; the company with the second highest chemical operating profits is Monsanto, which moved up from fourth position in 1984. Dow, second in operating profits in 1984, fell to sixth place in 1985. In terms of chemical operating profit margin, the top producer is Sigma-Aldrich at 28.6%. Sigma-Aldrich, a producer of laboratory and reagent chemicals, also headed that category in 1984. Tied with the second best chemical operating profit margin last year at 25.4% were Big Three Industries, which had been fourth the year before, and GAF, which had been seventh in the category in 1984.

Dow Chemical remains the largest company in terms of identifiable chemical assets, with a total of $8.05 billion in 1985. Second, as it was the previous year, is Du Pont, with $7.89 billion in chemical assets. In third place again is Exxon, chemical operations of which include identifiable assets valued at $5.34 billion.

Once again, the company recording the best return on chemical assets (chemical operating profit as a percentage of identifiable chemical assets) is Freeport-McMoRan, at 48.8%. Second best in that category last year was First Mississippi at 45.4%, up from fourth place in 1984. Third best, as the year before, was GAF at 42.6%. Those companies, all of which focus on specialty products, receive a return on assets far higher than that recorded by the larger, commodity chemical producers. Du Pont's return on chemical assets, for example, was 11.0%, and Dow's was just 5.1%, 61st in that ranking. □

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CHEMICAL & ENGINEERING

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Cuba bolsters applied science, with emphasis on biotechnology
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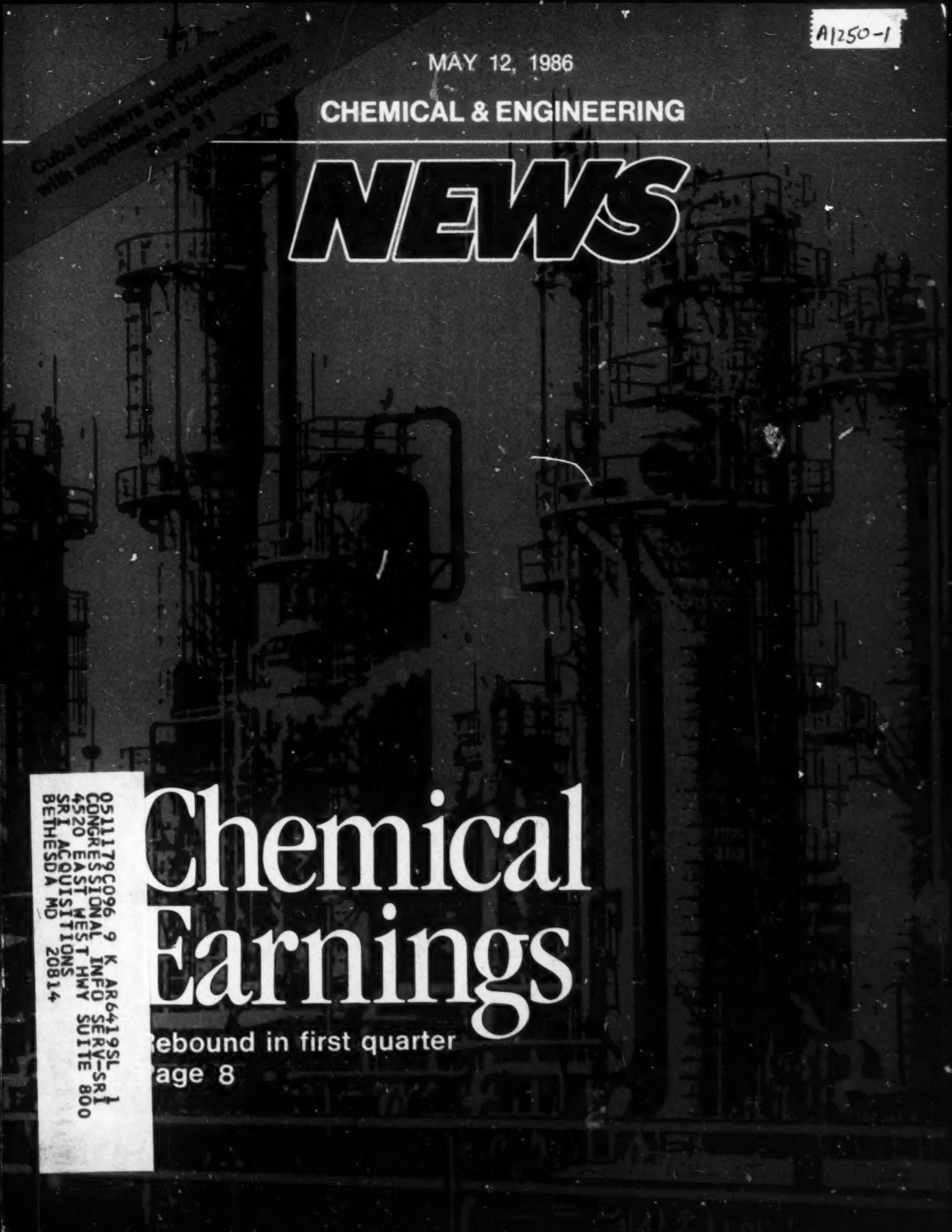

Chemical Earnings

Rebound in first quarter
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CHEMICAL & ENGINEERING
NEWS
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- **U.S.S.R. nuclear reactor accident puts U.S. government wheels in motion, monitoring fallout, activating interagency panel, triggering Congressional hearings.** Page 4
- **Du Pont will buy agricultural chemicals subsidiary of Shell Oil for undisclosed sum.** Page 5
- **EPA officer recommends delaying permit for chemical waste burn at sea until issues of concern to citizens, environmental groups have been resolved.** Page 6
- **Studies on design and operation of facilities that process or store toxic chemicals and on ways to mitigate effects of accidental chemical releases commissioned by AIChE safety center.** Page 6

Business

Earnings of 30 top U.S. chemical companies increased an average of 14% in the first quarter over first-quarter 1985. **Page 8**

Government

Reorganization of NSF's chemistry division proposed to make it more responsive to changes in chemical research. **Page 14**

Science

Town meeting approach used by Berkeley researchers, EPA official to explain recombinant bacteria tests to residents; phytic acid and blood oxygen; expansion polymerization coatings; IUPAC affiliate numbers increasing; semiconductor research; reactions of metal cluster ions; and biological reductions. **Page 17**

Education

Retired chemists in society's Delaware Section enjoy new careers teaching chemistry in local elementary schools. **Page 27**

Books

"Modern Science and Human Values" by William Lowrance offers more insight than answers. **Page 40**

ACS News

The society's Health & Safety Referral Service, which relays inquiries on chemistry-related matters, headed by Maureen Matkovich. **Page 42**

Special Report

Cuban science is emphasizing biotechnology and research on the island's chief crop, sugarcane, although hampered by limited personnel and lack of modern lab equipment. **Page 31**

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Chemical Earnings Revived In the First Quarter

Rebound by 15 largest companies ends five-quarter span of declining earnings, but income of 15 smaller firms falls a composite 9%

David Webber, C&EN New York

Many of the 30 largest U.S. chemical companies began to reap the benefits of last year's restructurings and work-force reductions during the first quarter of 1986. They were also aided by lower feedstock costs as a result of falling oil prices.

Working with lower payrolls and without many unprofitable lines of business, the 15 biggest firms recorded a composite 20% increase in net income, compared with first-quarter 1985. At the same time, however, the earnings of the smaller 15 companies, many of which depend on currently sluggish specialty markets, declined a composite 9% during the same period. In total, combined first-quarter net income for the 30 largest chemical firms rose 14%.

Pricing continued to bedevil the chemical industry, however. The producer price index for chemicals and allied products increased just 0.7% over first-quarter 1985, the fourth consecutive business quarter during which chemical prices rose less than 1%. As a result, even though companies reported sizable increases in sales volume for many chemical commodities, sales revenues climbed just 7% for the 15 largest firms, 3% for the other 15 companies, and just 6% overall. Still, the 6% year-to-year gain was the best since second-quarter 1984.

Many companies recorded solid success in their efforts to bolster the bottom line. Profit margins (after-tax earnings as a percentage of sales) jumped to 5.0% overall from 4.7% in first-quarter 1985 and from a recent nadir of 3.1% in fourth-quarter 1985.

On the other hand, those notable improvements were made against a poor first-quarter 1985, a period in which sales had declined 2% and earnings had fallen 24% from first-quarter 1984. A look at 12-month running data demonstrates that the industry still has a way to go to regain former financial performance levels. For the 30 firms, for example, composite net income for the 12 months ending March 31, 1986, was 25% below that for the 12 months ending March 31, 1985. Over the same span, composite sales rose just 1%, and overall profit margins slipped to 3.7% from 5.0%. Only 11 companies in the group raised earnings on a 12-month running basis.

Oil and gas producers and diversified manufacturing companies with substantial chemical operations did not fare nearly so well as the largest chemical companies. Stunned by the collapse of oil prices, the energy firms, though generally aided by profits from their chemical segments, mostly recorded large decreases in corporate net income during the first quarter. Composite earnings for 16 oil and gas companies fell 10% on a 12% decline in sales. Eleven firms in the group recorded lower net income or a deficit for the quarter. Only Enron reported a sales increase.

Because of the wider range of mar-

Chemical industry leaders for the first quarter

Sales				Earnings[a]			Profitability		
Rank 1986		$ Millions	Rank 1985		$ Millions	Rank 1985		Earnings as % of sales	Rank 1985
1	Dow Chemical	$2852.0	1	Dow Chemical	$175.0	1	International Flavors	14.9%	1
2	Monsanto	1745.0	3	Monsanto	118.0	2	Freeport-McMoRan	10.2	4
3	Union Carbide	1669.0	2	PPG Industries	69.2	3	Nalco Chemical	8.6	2
4	W. R. Grace	1250.5	4	Celanese	51.0	7	Ethyl	8.5	8
5	PPG Industries	1140.0	5	American Cyanamid	49.1	5	Petrolite	7.7	3
6	American Cyanamid	917.9	6	Hercules	45.4	8	Air Products	7.7	6
7	Chesebrough-Pond's	828.5	b	Chesebrough-Pond's	42.1	b	Loctite	7.2	5
8	Celanese	747.0	7	Air Products	39.1	9	Rohm & Haas	7.2	10
9	Hercules	645.2	8	Rohm & Haas	38.3	6	Hercules	7.0	14
10	National Distillers	631.5	9	Union Carbide	37.0	4	Morton Thiokol	7.0	12

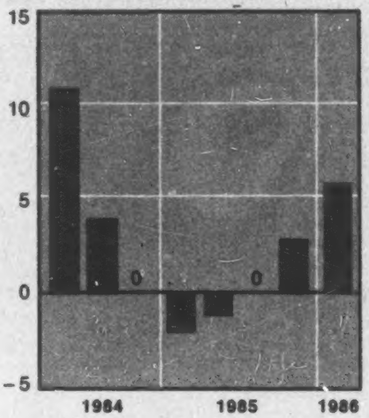
a After taxes. b Not meaningful since Chesebrough-Pond's not considered a chemical company until acquisition of Stauffer Chemical in March 1985. Note: For 30 companies listed on page 10.

Chemical industry 1986 first-quarter results

- Sales increased 6%
- Earnings rebounded
- Profit margins revived
- Production rose strongly
- Prices stagnated again

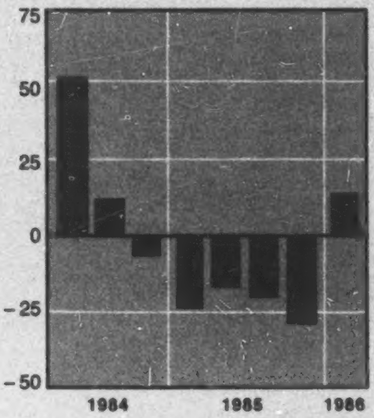
Sales

% change from year-earlier quarter



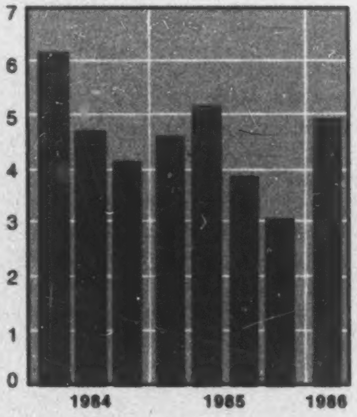
Earnings

% change from year-earlier quarter



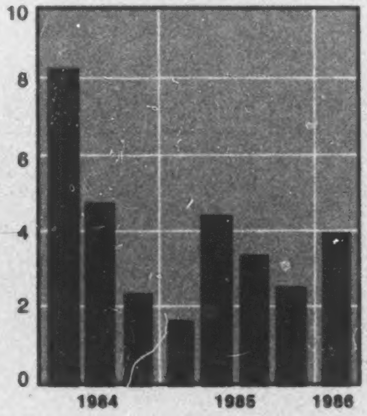
Profit margins

After-tax earnings as % of sales



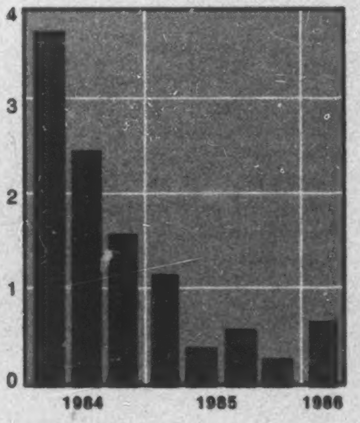
Production

% change from year-earlier quarter



Prices

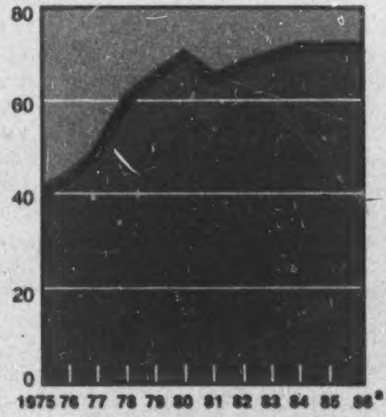
% change from year-earlier quarter



Sales in 1986 will be level, but net income will surge, pushing profit margins higher

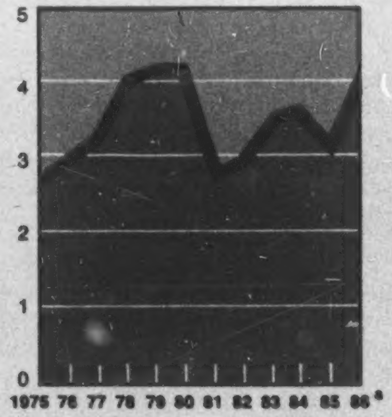
Annual sales

$ Billions



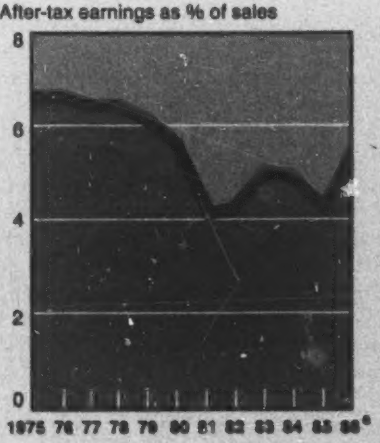
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



a C&EN estimates. Note: All sales, earnings, and profit-margin statistics are based on combined results of the 30 companies listed on page 10.

Chemical company earnings rose 14% in the first quarter

	FIRST-QUARTER 1986						12-MONTH RUNNING DATA			
	Sales	Earnings[a]	Change from 1985		Profit margin[b]		Change from 1985		Profit margin[b]	
	($ millions)		Sales	Earnings	1986	1985	Sales	Earnings	1986	1985
Air Products[c]	$ 508.9	$ 39.1	11%	10%	7.7%	7.8%	9%	8%	7.8%	7.8%
American Cyanamid[c]	917.9	49.1	4	15	5.3	4.8	−6	−22	4.2	5.1
Celanese[c]	747.0	51.0	0	42	6.8	4.8	−6	26	6.3	4.7
Chemed	94.4	4.3	6	8	4.6	4.5	7	1	4.8	5.1
Chesebrough-Pond's[c]	828.5	42.1	101	205	5.1	3.4	89	56	3.1	3.8
Crompton & Knowles	62.1	2.0	11	65	3.2	2.2	5	14	3.5	3.2
Dow Chemical[c]	2,852.0	175.0	4	59	6.1	4.0	3	−73	1.1	4.0
Essex Chemical	50.7	2.5	11	6	5.0	5.3	6	−21	4.4	5.9
Ethyl	378.0	32.0	0	14	8.5	7.5	−5	5	9.1	8.2
First Mississippi	65.5	−23.2	−4	def	def	5.7	−2	def	−5.2	7.3
Freeport-McMoRan	159.9	16.4	−26	−4	10.2	7.9	−22	−30	10.6	11.8
W. R. Grace[c]	1,250.5	−3.1	6	def	def	0.1	254	−33	0.5	2.8
H. B. Fuller	119.2	2.8	10	58	2.3	1.6	−16	−23	2.0	2.1
Hercules[c]	645.2	45.4	1	27	7.0	5.6	0	−25	5.5	7.4
International Flavors	148.0	22.1	22	25	14.9	14.5	11	9	14.0	14.4
International Minerals[c]	416.5	−2.2	1	def	def	7.4	−6	−79	1.4	6.6
Loctite	66.8	4.8	24	12	7.2	7.9	7	−2	9.1	10.0
Lubrizol	276.8	18.5	8	−5	6.7	7.6	6	−15	6.4	7.9
Monsanto[c]	1,745.0	118.0	7	36	6.8	5.4	4	−39	3.1	5.3
Morton Thiokol[c]	518.5	36.1	4	12	7.0	6.5	0	11	6.8	6.2
Nalco Chemical	178.5	15.4	9	−12	8.6	10.7	3	−4	10.2	11.0
National Distillers[c]	631.5	19.3	10	−6	3.1	3.6	5	10	2.5	2.4
Olin[c]	451.4	25.3	−5	108	5.6	2.6	−14	−28	3.1	3.7
PPG Industries[c]	1,140.0	69.2	10	−2	6.1	6.8	85	55	3.8	4.6
Pennwalt	267.1	13.0	8	90	4.8	2.8	67	5	5.7	9.0
Petrolite	75.8	5.8	−2	−17	7.7	9.1	−23	−27	6.9	7.3
Reichhold Chemicals	209.7	1.1	13	−56	0.5	1.3	9	def	−0.8	2.9
Rohm & Haas[c]	540.8	38.3	−2	−5	7.1	7.3	0	−11	6.8	7.6
Union Carbide[c]	1,669.0	37.0	0	−26	2.2	3.0	−9	−34	2.6	3.6
Witco	343.6	14.1	−6	28	4.1	3.0	−4	2	4.1	3.9
Total 15 largest companies	**$14,862.7**	**$739.6**	**7%**	**20%**	**5.0%**	**4.4%**	**−2%**	**−28%**	**3.4%**	**4.6%**
Second 15 companies	**$ 2,496.0**	**$131.4**	**3%**	**−9%**	**5.3%**	**6.0%**	**22%**	**−10%**	**5.2%**	**7.0%**
GRAND TOTAL	**$17,358.7**	**$871.0**	**6%**	**14%**	**5.0%**	**4.7%**	**1%**	**−25%**	**3.7%**	**5.0%**

a Excludes all significant extraordinary and nonrecurring items. b After-tax income as a percentage of sales. c One of 15 largest companies. **def** = deficit.

kets into which they sell, the group of 21 diversified manufacturers analyzed by C&EN reported more varied results. Du Pont, for instance, despite its large energy segment, boosted its net income 47% over first-quarter 1985. Last year, the company reduced its payroll substantially through a very large workforce reduction program. And Allied-Signal, based on restated statistics that partly take into account the merger of Allied and Signal last year and the spinoff of many lines of business into the Henley Group, increased earnings 39%.

Still, net income fell on a year-to-year basis at 11 of the firms. Overall, earnings dropped 2% on a 1% gain in sales. Koppers, NL Industries, and U.S. Steel lost money in the quarter, and double-digit earnings declines were registered by Aluminum Co. of America, Eastman Kodak, FMC, Georgia-Pacific, and Tyler (excluding the benefits of the settlement of a patent infringement suit).

Dow Chemical, with a 59% increase in net income on 4% sales growth, remained the top chemical company in terms of both revenues and earnings from operations. Dow chief executive Paul F. Oreffice attributes the gains to cost-reduction programs, including a 2700-person staff cut, and "an improved environment for many Dow businesses." According to Oreffice, some of the best performances in the quarter were turned in by the company's consumer specialties operations, particularly by Merrell Dow Pharmaceuticals, and by the epoxy and urethane chemicals groups.

Air Products had another solid quarter. The company has largely avoided the financial ups and downs of its other major competitors over the past two years. During first-quarter 1986, pretax operating profits rose 13% for its industrial gases segment and 8% for its chemicals segment (after the exclusion of nonrecurring items). Air Products continued to struggle with its engineering services segment, however,

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 37 oil and diversified companies, each with more than $200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 40% of its sales in chemicals, and its chemical operations must be the largest single portion of the total operations. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

which lost $2.3 million before taxes.

After losing $59 million in fourth-quarter 1985, Monsanto resumed making money in first-quarter 1986, recording a 36% increase in net income compared with last year's first quarter. The company's results benefit in total from the inclusion of sales and earnings by the units added in last October's acquisition of G. D. Searle, as well as from the exclusion of sales and earnings by businesses both already sold and planned for shutdown or sale as part of the restructuring launched last year. In particular, Monsanto boosted pretax income from its chemicals segment, which has sold or will be selling several major facilities, by 161%. Pretax profits from crop chemicals inched up 2%, thanks to improved marketing of Roundup herbicide and despite lower shipments of Lasso herbicide.

Energy, diversified firms' earnings fell in first quarter

	% chemical sales	FIRST-QUARTER 1986					
		Sales	Earnings[a]	Change from 1985		Profit margin[b]	
		($ millions)		Sales	Earnings	1986	1985
OIL AND GAS COMPANIES							
Amoco	10%	$ 5,900.0	$331.0	−16%	−30%	5.6%	6.8%
Ashland	18	1,800.0	39.0	0	179	2.2	0.8
Atlantic Richfield	17	4,287.0	288.0	−26	−23	6.7	6.5
Chevron	6	8,900.0	320.0	−29	−10	3.6	2.8
Diamond Shamrock	18	950.3	−10.0	0	def	def	6.2
Enron	6	3,312.4	81.7	24	−24	2.5	4.0
Exxon	7	22,243.0	1.9	−4	52	0.0	0.0
Kerr-McGee	14	718.9	22.1	−11	−22	3.1	3.5
Mobil	4	14,100.0	440.0	−7	38	3.1	2.1
Occidental Petroleum	10	3,630.8	74.2	−2	−10	2.0	2.2
Phillips Petroleum	15	3,113.0	69.0	−21	−40	2.2	2.9
Shell Oil	16	4,666.0	276.0	−2	−7	5.9	6.2
Sun Co.	3	3,350.0	146.0	−9	15	4.4	3.5
Texaco	3	9,600.0	328.0	−20	59	3.4	1.7
Unocal	11	2,279.6	70.2	−18	−61	3.1	6.5
Williams Cos.	24	796.4	14.2	−24	−51	1.8	2.8
DIVERSIFIED MANUFACTURERS							
Allied-Signal	23	2,909.0	186.0	18	39	6.4	5.4
Aluminum Co. of America	5	1,177.3	1.4	−10	−79	0.1	0.5
Borden	33	1,136.4	36.7	5	6	3.2	3.2
Borg-Warner	28	895.5	49.4	12	11	5.5	5.6
Du Pont	38	7,169.0	404.0	−1	47	5.6	3.8
Eastman Kodak	22	2,345.4	48.6	10	−58	2.1	5.4
Engelhard	26	526.2	11.4	−9	−3	2.2	2.0
FMC	39	752.3	20.1	0	−54	2.7	5.8
GAF	50	176.0	15.0	0	34	8.5	6.3
General Electric	8	5,880.0	537.0	−5	5	9.1	8.2
Georgia-Pacific	4	1,604.0	30.0	2	−39	1.9	3.1
Kaiser Aluminum	13	582.2	7.2	15	nm	1.2	def
Koppers	44	261.7	−0.6	1	def	def	def
Eli Lilly	22	988.3	172.6	9	7	17.5	17.7
3M	15	2,069.0	181.0	9	7	8.7	8.9
Merck	13	921.1	157.8	8	20	17.1	15.4
NL Industries	40	359.2	−1.1	10	def	def	1.3
Pfizer	10	1,032.1	168.9	8	15	16.4	15.5
Tyler	41	230.2	0.9	5	−52	0.4	0.9
U.S. Steel	6	4,651.0	−257.0	−7	def	def	def
Vulcan Materials	30	200.6	6.9	1	−4	3.4	3.6

[a] From continuing operations excluding nonrecurring and extraordinary items. [b] Earnings as a percentage of sales. def = deficit. nm = not meaningful.

Problems persisted, however, in the animal sciences unit, which lost $12 million before taxes, compared with a $13 million deficit in first-quarter 1985; electronic materials, which lost $15 million before taxes; and Fisher Controls, which lost $3 million before taxes. The pharmaceuticals unit lost $30 million pretax, largely offsetting the $38 million pretax profit turned in by the NutraSweet artificial sweetener operation. Monsanto is now isolating the costs of part of its biotechnology-based program. The unit, biotechnology product discovery, lost $8 million before taxes on no sales in first-quarter 1986.

Weak prices and sales volumes for fertilizers and the oil price drop overrode a big increase in pretax income from specialty chemicals in W. R. Grace's first-quarter loss of $3.1 million. Grace's specialty chem-

Energy companies helped by chemical earnings

The oil price collapse was bound to bring down corporate net income, but oil and gas companies could find some solace during the first quarter in the performance of their chemical operations. In most cases, after-tax earnings from the chemical businesses owned by energy companies increased sharply compared with first-quarter 1985. Exxon, Shell, and Enron (formerly HNG/InterNorth) registered triple-digit percentage gains in chemical net income, Mobil reversed a loss in the year-earlier quarter, and other companies prospered in the chemical arena as well.

Energy companies with chemical operations benefited from lower feedstock costs for petrochemicals and improvements in operating efficiency. Those positive factors more than offset the industry's continuing difficulty in raising product prices.

The most spectacular gain in the first quarter was made by Shell Oil's chemical segment, which increased net income 454% compared with first-quarter 1985. Shell Oil president John F. Bookout says that both lower raw material costs and higher agricultural chemical sales, coupled with lower manufacturing shutdown maintenance costs this year, were chiefly responsible for the strong profit increase. Still, he notes, selling prices were lower in nearly all business lines, particularly in polymers, intermediates, and solvents.

Enron, citing lower feedstock costs and higher margins, increased its chemical operations earnings 240%. Exxon, which has the largest chemical operation of any oil and gas producer, reported a 156% increase in after-tax income from chemicals. In the U.S., Exxon chemical net income rose to $61 million from $36 million in first-quarter 1985, a 69% increase. Overseas, Exxon chemical earnings jumped to $54 million from just $9 million in the year-earlier period, a 511% improvement.

Mobil was able to reverse last year's first-quarter deficit through better petrochemical margins in the U.S. and bringing its petrochemical plant in Saudi Arabia to full operational status. During first-quarter 1985, that facility was in its startup phase. Amoco's chemical operations earned 47% more in first-quarter 1986 than in last year's first quarter. Sales volumes for most chemical and polymer products were higher, and some commodity chemical margins improved, the company says. On the other hand, Amoco notes, results for synthetic fabrics and fibers and specialty chemical products declined from the year-earlier period.

Chevron attributes the 55% jump in its chemical after-tax earnings to higher sales volumes for industrial chemicals, primarily ethylene, polyethylene, and *p*-xylene, as well as lower feedstock costs. At Atlantic Richfield, Arco Chemical—the corporation's specialty and intermediate chemical operations—reported a 19% rise in net income, and Lyondell Petrochemical, Arco's integrated petroleum-processing business, earned $32 million compared with a loss of $26 million in first-quarter 1985.

Other energy companies not breaking out chemical after-tax results still reported strong gains by their chemical operations. At Diamond Shamrock, chemical sector earnings increased, the company says, because of lower energy costs and better chlorine demand from customers in the plastics industry.

By contrast, the Williams Cos.' Agrico Chemical subsidiary, which produces fertilizer products, recorded a pretax loss of $8.8 million in the quarter, compared with a $1.6 million pretax profit in first-quarter 1985. And Ashland Oil, though terming its chemical operation results "satisfactory," notes that operating income was below the year-earlier level.

	First-quarter earnings on chemical operations[a]		
$ Millions	1986	1985	% change
Amoco	$ 72.0	$49.0	47%
Atlantic Richfield	25.0	21.0	19
Chevron	31.0	20.0	55
Enron	10.7	3.1	240
Exxon	115.0	45.0	156
Mobil	32.0	−7.0	nm
Shell	72.0	13.0	454

a After-tax earnings. nm = not meaningful.

icals business earned 31% more before taxes than a year earlier, but agricultural chemicals lost $12 million pretax, and natural resources earned 30% less pretax than in first-quarter 1985. The company's smaller restaurant and general business groups reported good gains. In its financial statement, Grace excludes losses incurred in first-quarter 1986 by its retail operations. Those deficits are being deferred and will be charged against the expected gain when the company sells its interest in Herman's Sporting Goods and, as planned, the rest of its retail group.

Also suffering from the slumping farm economy was International Minerals & Chemical. IMC's troubled fertilizer segment lost $3 million before taxes in the quarter. President George D. Kennedy, who has been forced to issue a stream of downward revisions on earnings forecasts over the past half year, warns that operating results for second-quarter 1986 (IMC's fiscal fourth quarter) could be down from recent predictions because of a disappointing spring fertilizer season.

Among the 15 smaller companies, Pennwalt raised net income 90% on an 8% sales gain. The company, which restructured extensively last year, reports significantly better results for its chemicals group, thanks to higher earnings by fluorochemicals and a return to profitability by the inorganic chemicals division—mainly the result of closing its unprofitable Wyandotte, Mich., chloralkali plant late last year. Pretax chemical group profits, which accounted for 83% of pretax earnings, jumped 22% in the first quarter. Pennwalt's pharmaceuticals group also fared well, the company says, with earnings before taxes exceeding $4 million after a loss in the year-earlier quarter. Only the equipment group faltered; its pretax income fell 93%. □

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CHEMICAL & ENGINEERING
NEWS

C_1 chemistry thriving despite changing energy environment
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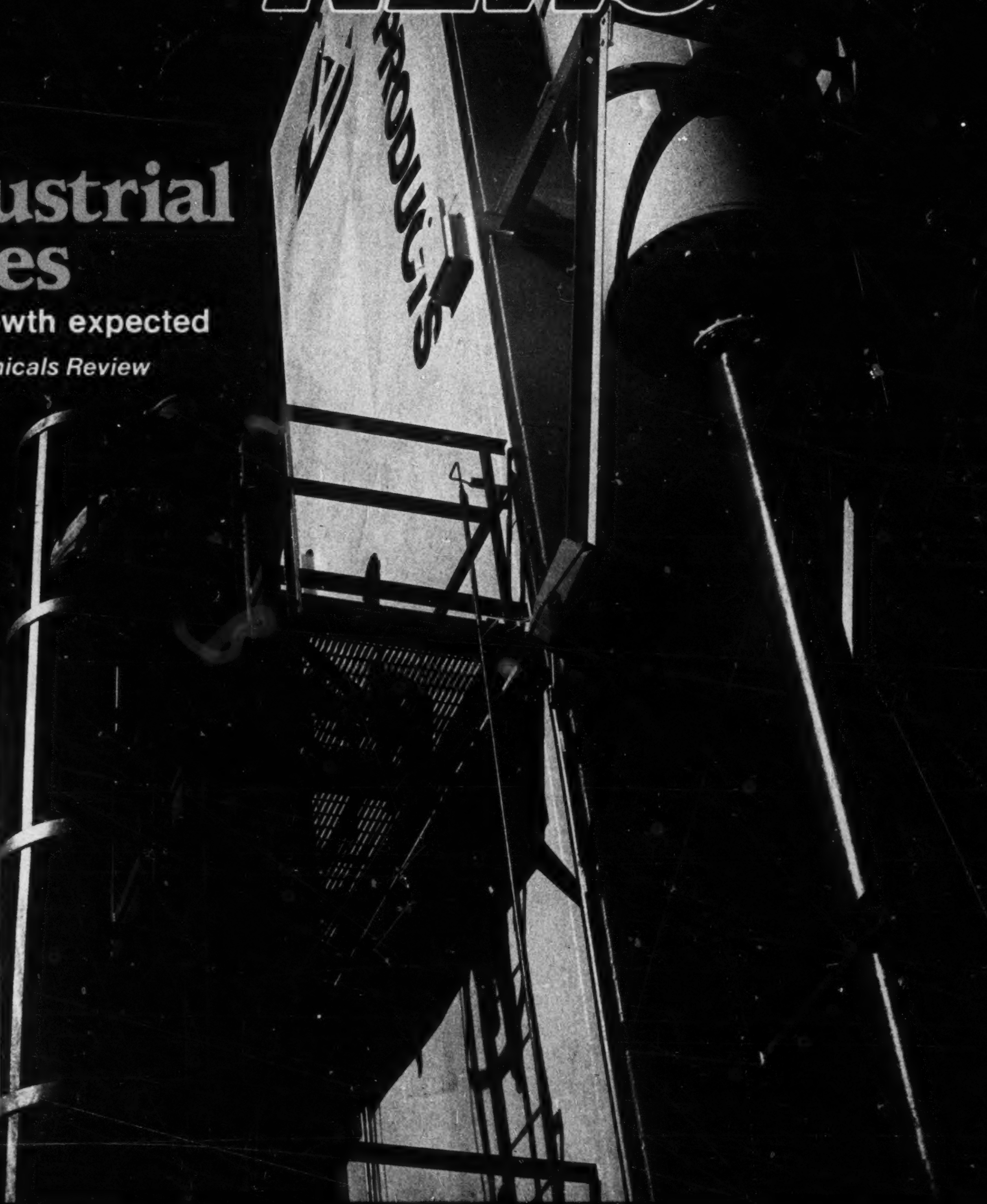

Industrial Gases

Little growth expected

A Key Chemicals Review
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CHEMICAL & ENGINEERING
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Celanese has boosted income despite lower sales, by changes in its organizational structure, R&D emphasis, among others. **Page 19**

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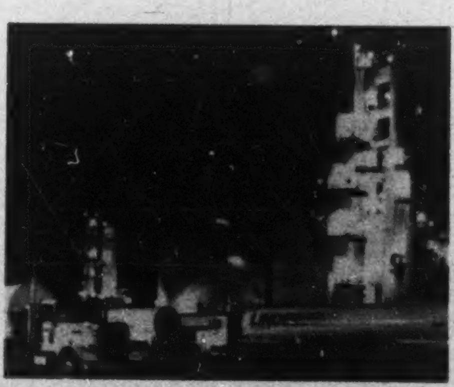


News Focus

C_1 chemistry R&D flourishes, indeed has led to some commercial development, in spite of the fact that the oil shortage that gave the technology its impetus is now an oil glut. Page 7

Major Industrial Gases: Demand Edging Upward This Year

Stepped-up demand for uses will help plant capacity utilization and keep profit margins rising; price competition will remain strong

Bruce F. Greek, C&EN Houston

Demand for major-volume industrial gases will swing upward slightly this year because most large uses of nitrogen, oxygen, carbon dioxide, argon, and hydrogen, as well as many small uses, will increase. Capacity utilization of most plants will be high, including the new plants started up last year and early this year.

Price competition will remain strong and not damage margins, as producers further emphasize the service aspects of supplying industrial gases.

Demand for nitrogen and oxygen in 1986 contrasts with last year's demand, which declined slightly as major consuming industries such as chemicals and steel experienced difficult times. Currently, demand by both these industries, as well as others, is increasing and is expected to continue to do so throughout this year and next. The weakest parts of industrial gas demand in 1986 and later will be in oil production uses, both in enhanced oil recovery and in well stimulation.

Carbon dioxide producers again will have to cope with the problem of limited crude feedstock supply and probably will sell less product than they did last year because of a decline in feedstocks. That problem continues to vary geographically and among producers, and it changes as new sources replace old ones that have declined or ended. Because most carbon dioxide for merchant sale will be recovered from coproduct gas streams of various chemical processes for at least five years, the supply situation also will change as chemical processing changes.

Key Chemicals

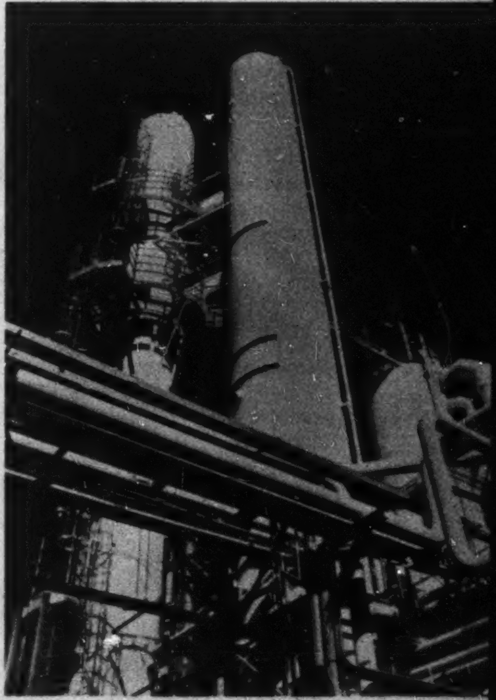
The industrial gases industry is changing in ways other than in sales volume improvement. Great strides have been made in lowering the cost of air separation and storage of liquefied gases, and further efficiencies are expected to develop. Major changes occurred both in delivering the gases to consumers and in how consumers are using the gases in their industries. Pipeline systems in areas of large demand for industrial gases are being expanded. In some areas, new pipeline systems are being planned. Rail and truck delivery of liquefied gases is expanding, as is on-site smaller-scale production through adsorption and membrane technologies. All of these moves result from the need by industrial gas consumers for more service.

The array of delivery systems and use-point storage facilities suggests that the industrial gases business has become more of an equipment and service business than a processing business. Most producers also sell equipment to users of the gases. They instruct consumers in use of the equipment, monitor operations, and develop new equipment, all as part of their services.

Nitrogen sales to the electronics industry is a case in point. Much of the nitrogen sold to or produced on site for the electronics industry meets the "electronics grade"—99.9999% pure. However, as technology and types of components produced by the electronics industry change, demand grows for still higher levels of purity. Also, contamination picked up in piping systems beyond the initial delivery point is pushing companies to pursue a system for final purification at use sites.

Such demands cause industrial gases to be more capital-intensive. They also increase service requirements. Producers will require an ever closer working relationship with consumers to avoid underusing high-cost facilities.

For some details of the near-term outlook for nitrogen, oxygen, and carbon dioxide, please see the following pages.



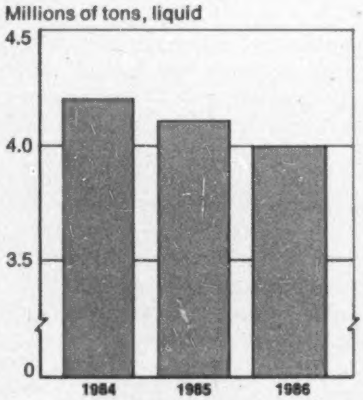
Union Carbide Linde division's air separation plant at Deer Park, Tex.

Carbon dioxide

CO_2

- ***Demand strong***
- ***Supply tight***
- ***Prices improving***

PRODUCTION (nonoilfield)



Note: Excludes CO_2 from natural sources consumed in enhanced oil recovery.

MAJOR PRODUCERS

Amerigas (UGI Corp.), BOC Group, Cardox (division of Liquid Air), Chemetron, Liquid Carbonic

HOW MADE

Recovered from gas streams involved in making ammonia, hydrogen, ethanol by fermentation, and other chemicals, and from natural sources.

MAJOR END USES

Refrigeration 40%, beverage carbonation 20%, chemical manufacture 10%, metals fabrication 10%, enhanced oil recovery 10%

FOREIGN TRADE

Negligible

PRICE

Varies widely with location, averages about $70 per ton

Output of recovered carbon dioxide will decline in 1986, keeping a crimp on sales volume. This year, suppliers to the merchant market are expected to have less carbon dioxide available than they generated last year. Demand for merchant carbon dioxide, however, will absorb nearly all that producers can purify.

The merchant market accounts for a tiny fraction of the total demand for carbon dioxide. Demand for use in enhanced oil recovery (EOR) and in making urea and a few inorganic carbonates is much larger. Other than minor quantities of carbon dioxide purchased for short-term EOR efforts (mostly experimental for the particular geologic formation) all of the carbon dioxide used in EOR comes from underground sources. This natural carbon dioxide is a part of natural gas production and, for some wells, may be the dominant gas. The carbon dioxide is separated from the hydrocarbon and other gases produced from a well, transported by pipeline to the site of an EOR project, then reinjected into a formation to move the oil to a well bore. Frequently, the carbon dioxide produced at one well and used at another remains the property of a single company and never enters the commercial scene. Practically all of the carbon dioxide involved in EOR never becomes reported production.

Similarly, a large fraction of the carbon dioxide coproduced with ammonia will be consumed on site to make urea. Much of this captively consumed carbon dioxide also is not reported production. Estimate of the quantity of carbon dioxide required for urea production in 1986, based on a requirement of 0.75 ton of carbon dioxide per ton of urea, is nearly 5 million tons, if urea output this year totals 6.5 million tons. Both urea and ammonia production is forecast to decline in 1986 because of lower fertilizer demand.

Merchant producers of carbon dioxide will continue to face a difficult supply situation in 1986 because the decline in ammonia production moves with the decline in urea production. Ammonia plants account for about 70% of the merchant carbon dioxide. Lesser quantities are obtained as coproducts of making chemicals (largely ethylene oxide), of making ethanol by fermentation, and of making hydrogen. All of these sources are interruptible because demand for the primary product changes with time. That causes scheduling problems for carbon dioxide sellers.

Even with the supply limitations and high costs of transportation of carbon dioxide in liquid and solid forms, merchant suppliers are developing new markets and expanding existing markets. Some markets are expanding rapidly, and suppliers have to hustle to meet the demand. The two largest markets (refrigeration and carbonation) are propelled by consumer demand following demonstrations of improved technologies. The other uses, mostly industrial, are widely varied and are not growing much.

Nitrogen competes with carbon dioxide in many refrigeration uses. When energy costs rose rapidly, nitrogen lost market share but now may be regaining it, especially with prevailing supply limitations for low-cost carbon dioxide. Because of physical property differences, carbon dioxide has less cooling effect than does the equivalent weight of nitrogen. But the advantage of using nitrogen is offset by other factors, especially by cost at the point of use.

Carbonation also continues to be a growing use of carbon dioxide. Growth in consumption of soft drinks continues to outpace population growth, aided by marketing ploys of the makers. At the same time, the "light beers" are growing very well, requiring increasing amounts of carbonated water for production.

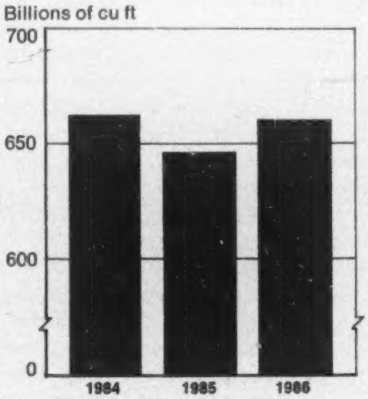
Most other uses of carbon dioxide—welding, inert atmospheres, pressurization, and many others—are growing only slightly.

N_2

Nitrogen

- ***Demand to match 1984***
- ***Some uses down***
- ***Prices competitive***

PRODUCTION



Note: Reported production of gaseous and liquid forms.

MAJOR PRODUCERS

Air Products & Chemicals, BOC Group, Big Three Industries, Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air; pressure swing adsorption using various adsorbents; selective permeability through membranes

MAJOR END USES

Blanketing atmospheres for chemical processing 25%, enhanced oil recovery 25%, electronics manufacture 15%, metals treating and processing 15%, aerospace 5%

FOREIGN TRADE

Negligible

PRICE

50 cents per 100 cu ft

Commercial demand for nitrogen likely will recover this year from last year's slump, but it will not rise much above the 1984 level. Demand in 1986 is expected to be about 660 billion cu ft of nitrogen in both gaseous and liquid forms, excluding most of the nitrogen consumed at ammonia plants.

In 1985, output fell 2%, to a reported production of 647 billion cu ft from the 661 billion cu ft produced in 1984. But the 1984 final estimate was nearly 10% higher than the preliminary estimate. Even so, 1985 production at 647 billion cu ft was down more than 7% from the 700 billion cu ft forecast.

An upturn of nitrogen production to the 1984 level will result from a higher level of chemical manufacturing, some additional use in various metal processing and treating activities, a small gain in use of especially high-purity nitrogen for electronic components manufacturing, and more need for inert gas blanketing in petroleum refineries. The major exception to gains in nitrogen demand will be in the area of enhanced oil recovery (EOR).

Nitrogen in chemical manufacturing (excluding ammonia production) goes largely for blanketing and purging atmospheres. Processes requiring nitrogen blanketing include the drying of chemicals and other products and the blanketing of polymerization reactors. The outlook for this use of nitrogen generally is that it will follow the growth of the chemical industry but with a slightly better rate because of the more sophisticated processing required by the shift toward producing more specialty chemicals.

Use of nitrogen in EOR previously was growing rapidly. Now, with much lower crude oil selling prices, all EOR efforts, and especially those employing nitrogen, are being scrutinized closely for economic justification, and some are being shut down. EOR consumption of nitrogen is higher than has been reported because this area lends itself to captive use by a consumer utilizing a skid-mounted unit to separate nitrogen from air on site. (Coproduct oxygen-enriched air is vented because of the impracticality of moving oxygen a long distance.)

Nitrogen competes with carbon dioxide in EOR. The growth in the pipelines business to carry carbon dioxide from natural production sites to areas of consumption partially reduces demand for nitrogen because of greater availability and lower cost of carbon dioxide. Nitrogen will continue to be used in EOR work, however, because its physical properties are better than those of carbon dioxide for certain production conditions and because combinations of nitrogen and carbon dioxide sometimes provide the best EOR. However, rapid growth in this use of nitrogen is over until crude oil prices return to higher levels. As a result of the change in oil prices, minor growth is all that can be expected for this use of nitrogen in 1986. Its share of consumption with carbon dioxide for EOR also could begin to decline this year.

Blanketing atmospheres for electronic component manufacture has been another fast-growing use of nitrogen. But, in 1985, as a result of competition from imported chips, that use gained very little. Prospects for this year are for the same, with some possibility that consumption could decline even further, depending on electronics product demand and on changes in the technology of making components.

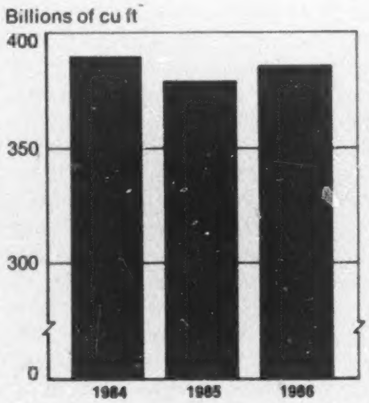
Among other important uses of nitrogen, metals and refrigeration, both significant merchant markets, continue to grow. The reason for the growth in metal processing stems largely from the cost-saving advantages that nitrogen offers. The refrigeration market is buoyed by the general public's seemingly insatiable appetite for fast foods, which require liquid nitrogen for flash freezing. These and other service-oriented merchant markets for liquid nitrogen continue to give merchant producers relatively good profits.

O_2

Oxygen

- ***Small demand rise***
- ***Capacity holding***
- ***Prices steady***

PRODUCTION



Note: Reported production of gaseous and liquid forms.

MAJOR PRODUCERS

Air Products & Chemicals, BOC Group, Big Three Industries, Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air; pressure swing adsorption using various adsorbents

MAJOR END USES

Primary metals manufacture 55%, chemical manufacture 20%, partial oxidation processes 10%, metals fabrication 5%

FOREIGN TRADE

Negligible

PRICE

54 cents per 100 cu ft

Demand for oxygen will remain on hold this year, as it has in the two previous years. A small gain in reported oxygen production in 1986 likely will bring the total back to 385 billion cu ft, in the middle of a 380 billion to 390 billion cu ft range for the annual reported production from 1984 to 1986.

Lack of demand growth for oxygen stems from its use pattern, dominated by production of metals (mostly steel but including some copper). Metals production still takes more than half of oxygen output, most of it tonnage production from on-site or nearby air separation plants. A small additional quantity of oxygen is used in fabrication of metals, again mainly steel, for cutting and welding.

The dominance of metals processing in oxygen consumption, especially steelmaking, had been expected to decline significantly in the early 1980s. Such uses as chemical manufacture and coal gasification were forecast to be growing rapidly by the middle of the decade. Although demand for chemicals based on oxidation processes has expanded about 5% a year, demand for coal gasification uses remains small with little probability of expansion during the rest of the 1980s. The demise of Synthetic Fuels Corp. indicates a bleak future for the near term in use of oxygen to aid gasification of coal.

Most of the small gain in consumption of oxygen in 1986, however, will be by the steel industry. After the extensive rationalization in that industry, the remaining steelmaking furnaces are the most efficient the industry has. These more modern furnaces generally require larger quantities of oxygen per ton of steel produced to gain their better efficiency. Besides consumption of steel tubing and plate by the oil production and refining industries, other demand for steel is forecast to give a small net gain in production over that of 1985.

Chemical uses of oxygen, at about one fifth of total consumption, are dominated by making ethylene oxide, which accounts for about 60% of the total chemical uses. Most, but not all, of the oxygen used in making chemicals is supplied by merchant producers. Purchased oxygen for making chemicals will remain the major source because of the flexibility permitted in plant operations, according to suppliers. Growth in chemical demand for oxygen will be larger than average growth in chemical production because of shifting from air oxidation. However, no major new technologies requiring large quantities of oxygen to make chemicals will become commercial soon.

Most other uses of oxygen are small, each requiring less than 5 to 10% of consumption. None of those uses and no new uses are forecast to grow fast enough to affect total demand significantly. Probably the brightest outlook for increased demand among the small uses belongs to the vast environmental area, dominated by sewage treatment.

Other water treatment processing with oxygen involves wastewater (black liquor) produced at pulp and paper mills and, to a lesser extent, wastewater streams at chemical and other industrial plants. Some of the oxygen required for treating wastewater streams is produced on site, and some is purchased as liquid. If ozone is the oxidant of choice, it may be made on site from purchased liquid oxygen.

Among other uses, a small and growing amount of oxygen is used in pulping processes, primarily aimed at reducing the air and water pollution problems caused by use of inorganic sulfur compounds and chlorine. The space program is another user of oxygen, but demand will be lower this year. Partial oxidation of heavy petroleum fractions to produce just hydrogen for hydrocracking or synthesis gas for chemicals may decline slightly in 1986 because of changes in imports of crude oil and of gasoline. Thus, small uses of oxygen will contribute nothing to growth in demand.

Thermoplastics for engineering will grow

Engineering thermoplastics, already a $1.7 billion business in the U.S., have plenty of growth left in them, at least through 1995. And they will continue to provide a good return on investment of most established producers active in high-margin materials.

However, says Richard M. Kossoff, president of R. M. Kossoff Inc., New York City, competition in engineering thermoplastics is certain to increase, and as it does it will put pressure on profit margins. For most producers, that will mean a lower return on investment, compared with what they had enjoyed in the past.

Kossoff told a recent meeting of the Chemical Marketing Research Association in New York City that, to counter this, engineering thermoplastic suppliers already are drawing up strategies to counter the new competition. Those strategies include ways to cut costs, increase

Nylon to stay highest-volume engineering thermoplastic . . .

Millions of lb	Volume 1985	Volume 1990
Nylon	415	570
Polycarbonate	320	490
Modified polyphenylene oxide[a]	160	230
Polyester[b]	125	220
Acetal	115	155
Polyphenylene sulfide	11	19
Polysulfone	6	8
Higher-performance polymers	3	21

a Also known as polyphenylene ether. b. Comprises polyester terephthalate and polybutylene terephthalate. Source: R. M. Kossoff Inc.

. . . but high-performance grades will grow fastest

Millions of lb	Volume 1985	Volume 1990
Polyacrylate	0.2	5.5
Liquid crystal polymers	0.2	3.0
Polyarylsulfone/polyether ketone	0.1	0.8
Polyetherether ketone	0.1	0.8
Polyetherimide	0.9	7.0
Polyethersulfone	1.3	3.1
Polyamide-imide	0.4	0.6
Other[a]	0.1	0.2
TOTAL	3.3	21.0

a Excludes captive. Source: R. M. Kossoff Inc.

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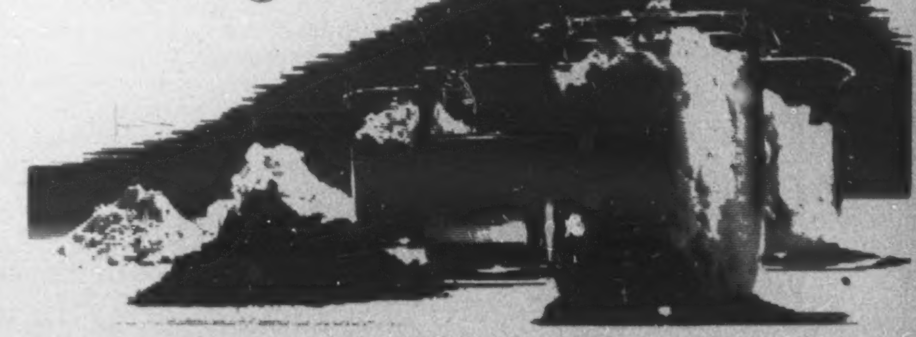
GENERAL ELECTRIC



CIRCLE 17 ON READER SERVICE CARD

SPECIALISTS IN ORGANIC DI-VALENT SULFUR COMPOUNDS

Polythiols-
Polymercaptans
-R-(SH)n

Dimercapto diethyl ether
$O(CH_2CH_2-SH)_2$

Glycol Dimercaptoacetate
$HS-CH_2COOCH_2$
$HS-CH_2COOCH_2$

Glycol Dimercaptopropionate
(Ethylene bis
(b-mercaptopropionate)
$HS-CH_2CH_2COOCH_2$
$HS-CH_2CH_2COOCH_2$

Pentaerythritol Tetra
(3-Mercaptopropionate)
$C(CH_2OOCCH_2CH_2-SH)_4$

Pentaerythritol
Tetrathioglycolate
$C(CH_2OOCCH_2-SH)_4$

Trimethylolethane Tri
(3-Mercaptopropionate)
$CH_3C(CH_2OOCCH_2CH_2-SH)_3$

Trimethylolpropane Tri
(3-Mercaptopropionate)
$CH_3CH_2C(CH_2OOCCH_2CH_2-SH)_3$

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CIRCLE 15 ON READER SERVICE CARD

average prices, and maintain their share of the market, especially in what they consider to be the best end-use segments.

New suppliers, Kossoff says, will have to adopt a "patient money" approach. That's because it usually takes from 10 to 15 years to achieve a positive, cumulative cash flow.

According to Kossoff, consumption of engineering thermoplastics in the U.S. reached 1.2 billion lb last year. Volume could have been higher had it not been for significant imports of finished products, such as cars, business machines, and electronics. Such imports should ease somewhat in 1986 and 1987, he says, as the dollar loses some of its strength, especially against the Japanese yen.

One notable trend has been what Kossoff calls the "explosion" of high-performance alloys, such as polycarbonate/polybutylene terephthalate. He sees volume of those alloys expanding from last year's 230 million lb to 400 million or 500 million lb in 1990. That's a 12 to 17% annual growth rate. Kossoff cautions, however, that although the trend toward alloys has been favorable for the companies that have developed them, it has caused confusion among end users.

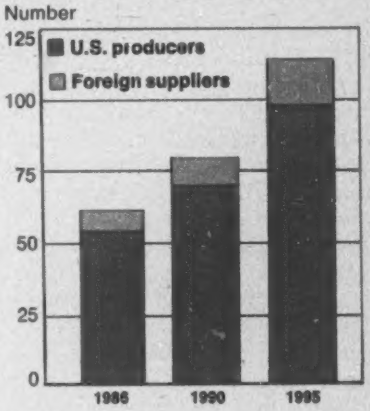
Total consumption of engineering thermoplastics in the U.S. is expected to grow about 8.2% per year through 1990, when volume likely will reach 1.7 billion lb. By then, these plastics may represent a $2.9 billion business. Between 1990 and 1995, Kossoff pegs the average annual growth rate at 9 to 11%, depending upon penetration into the market for exterior auto parts.

The volume leaders among such plastics are nylon and polycarbonate. But in addition to those and other "core" engineering thermoplastics, Kossoff notes that there is a group of high-performance polymers, including high-temperature grades and liquid crystal polymers, that should enjoy a hefty 45%-per-year annual growth rate through 1990.

But, while demand grows in the U.S., the engineering thermoplastics business will become more complex. As patents expire and foreign producers look for larger, faster growth markets, the U.S. becomes an obvious choice for investment, says Kossoff. As a result, the number of U.S. producers will increase, from 53 this year to 98 by 1995. If overseas exporters to the U.S. are included, the number of suppliers will be even higher—perhaps 115 in 1995. The rapid addition of alloys to existing product lines further increases the number of suppliers to the U.S. market.

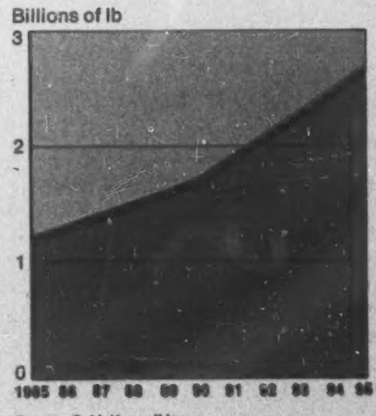
Already, several European companies, such as BASF, Akzo, and Imperial Chemical Industries, have entered the U.S. market via acquisition or by building plants here. Kossoff thinks that foreign firms will continue to acquire reinforced thermoplastics compounders as a means of getting into the U.S. market.

Number of producers and suppliers will increase



Source: R. M. Kossoff Inc.

Engineering thermoplastics to grow moderately



Source: R. M. Kossoff Inc.

So far, Japanese companies have mainly licensed their engineering thermoplastics technology in the U.S. By the 1990s, says Kossoff, at least one or two Japanese companies will start producing in the U.S., either jointly or alone. Some Japanese companies already ship compounded polymers from Japan to Japanese auto parts producers in the U.S. That trend will accelerate, says Kossoff, and will serve as a springboard for Japanese companies to produce the thermoplastics in the U.S.

The expected influx of new producers, as well as the proliferation of new alloys, will put a lot of pressure on profit margins in the 1990s, Kossoff says. Prices of raw materials now are going down, but if they start rising again, producers still will be hard-pressed to increase their prices. That will add to the pressure on profit margins, as will the ability of multimillion-pound customers to bargain for lower prices.

Some existing producers, with depreciated plants and a well-thought-out strategy, will be able to keep margins near (but in most cases, somewhat lower than) existing levels. Kossoff suggests that the return on investment for new capital may drop from the 25- to 35%-range to about 20 to 30% in the 1990s for some companies. New entrants, who will have to spend anywhere from $40 million to $100 million, probably will have to wait 10 or 15 years to achieve a cumulative positive cash flow, he says.

To cope with the lower anticipated profits and the structural changes that lie ahead in engineering thermoplastics, producers are changing their strategies. Some are integrating backward; others are developing multiproduct lines; still others are emphasizing specialties to increase profit margins. Meanwhile, the Pacific Rim will attract attention, because consumption of engineering thermoplastics there is expected to increase from 125 million lb last year to 230 million lb in 1990.

Regardless of the strategy, the critical factors, Kossoff says, will be their ability to cut costs, raise average selling prices, and maintain or increase market share. □

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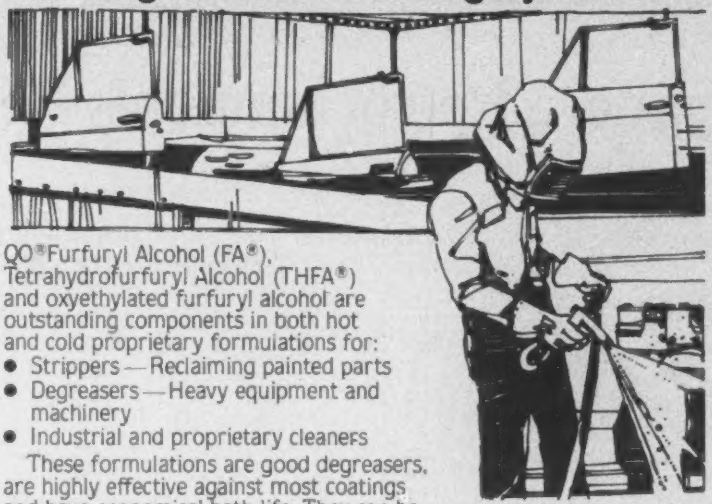

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CIRCLE 24 ON READER SERVICE CARD

ACS Committee on Professional Training 1985 Annual Report

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 1.5% in the 1984–85 academic year from the previous year. The number of master's degrees from these departments dropped less than 1%, and the number of Ph.D. degrees continued to rise for the sixth year in a row, this year 1.5%. These departments project increases for 1986 of 6% for bachelor's degrees, and 20% for both master's and Ph.D. degrees. (It should be noted, however, that these projections are usually higher than actual counts a year later.)

The percentage of baccalaureate graduates certified to ACS was 42%, down slightly from 43% last year. (Certified graduates are those who have completed the curriculum specified by the Committee on Professional Training and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

A total of 2463 of the bachelor's degree graduates from the approved schools were reported as planning to go to graduate school, and 2052 reported plans to go to professional schools.

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1984–85 by departments whose chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (Note: These departments are not required to report their data to CPT, so the number of departments included varies each year.) Also included is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are approved by the society.

The number of bachelor's degrees in chemical engineering from the 123 AIChE-ABET-accredited departments that reported in 1985 decreased 6% from the total reported by 120 departments in 1984, the second decrease in a row. These 123 departments reported an expected further decrease in bachelor's degrees of 14% in 1986. At the graduate level, the number of chemical engineering master's and Ph.D. degrees increased for the sixth year in a row. The number of master's degrees was up 3.6% from 1984, and the number of Ph.D.s was up 17%. Projected 1986 numbers of master's and Ph.D. degrees in chemical engineering from these schools are down less than 1% for master's degrees and up 44% for Ph.D.s.

Summary of totals from 1985 reports from approved schools

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, total	579	6263	3416	9679
Certified		2604	1417	4021
Noncertified		3659	1999	5658
Masters	316	1097	524	1621
Doctorates	186	1447	359	1806
CHEMICAL ENGINEERING				
Bachelors, certified	123	4797	1645	6442
Masters	118	1234	255	1489
Doctorates	104	383	35	418

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 579 colleges and universities on the approved list at the end of 1985. During the year the committee studied the chemistry programs of 163 of the approved schools and of 11 schools applying

Summary of data from approved schools, 1981–85

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates	Non-certified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1981	558	10,453	4337	6116	323	1609	187	1613
1982	561	9,866	4179	5687	322	1645	187	1683
1983	570	10,043	4233	5810	320	1569	189	1759
1984	577	9,819	4201	5618	321	1637	189	1777
1985	579	9,679	4021	5658	316	1621	186	1806
CHEMICAL ENGINEERING[a]								
1981	110	5,831	5831	—	106	1020	87	250
1982	113	5,963	5963	—	109	1171	92	293
1983	122	7,021	7021	—	116	1317	101	333
1984	120	6,866	6866	—	114	1436	101	357
1985	123	6,442	6442	—	118	1489	104	418

[a] Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

for ACS approval. Each evaluation involved a review of extensive documentary materials submitted by the department chair describing the current status of the program.

No schools were added to the ACS-approved list by the ACS Committee on Professional Training in 1985; one was put on probation; one was removed from probation; six continued on probation; and one was removed from the list.

Two issues of the CPT Newsletter were published in 1985. Distribution for each issue was approximately 12,000 college chemistry faculty members. Topics ranged from the importance of *CA* subscriptions in colleges to speaking and writing skills for students to a description of the CPT review process to provocative opinions and trends in chemical education. The second issue of the newsletter demonstrated its effectiveness as a vehicle for information exchange through a lively "Letters" column.

A Committee on Professional Training task force that met with representatives of the American Society of Biological Chemists developed a proposal for an ACS-approved chemistry degree with a biochemistry emphasis. After developing a tentative course of study and exploring the potential interest among chemistry students, CPT decided to present its proposal to the ACS Board of Directors at the April 1986 meeting.

A new edition of the ACS Directory of Graduate Research was published in November 1985. This edition contains 713 academic departments, 11,215 faculty members, and 58,760 publication citations. The DGR-Online, a computerized database of all the information in the printed version, also was updated. Special features of the on-line database that are not available in the printed version include data on faculty gender and controlled vocabulary for searching specific chemical research interests. The database is available through BRS Information Technologies. Further information on the file may be obtained from Cathy A. Nelson, ACS Office of Professional Training, 1155—16th St., N.W., Washington, D.C. 20036, telephone (202) 872-4599.

The committee continued its series of visits by two-person committee teams to constituent institutions. The purpose of these visits is for CPT members to learn more about current trends in chemistry education and about how the CPT Guidelines fit with these trends. The committee will evaluate this project after the final three scheduled visits have been completed in 1986.

Other CPT activities in 1985 included formation of a subcommittee to interact with the ACS Society Committee on Education Task Force on ACS Involvement in the Two-Year Colleges; survey of interest in a conference to address the concerns of small colleges on the ACS-approved list; initiation of a questionnaire to gather information on science/chemistry building construction; participation in an electronic mail experiment; and continuation of a project to computerize all data received from ACS-approved schools.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1985: Ivan Bernal, University of Houston; Larry K. Blair, Berea College; J. Nicholas Burnett, Davidson College; Charles P. Casey, University of Wisconsin; John W. Coutts, Lake Forest College; John P. Fackler Jr., Texas A&M University; Donald E. Jones, Western Maryland College; Jerry R. Mohrig, Carleton College; David L. Powell, College of Wooster.

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Barbara A. Gallagher, *committee secretary* after Aug. 1, 1985
Cathy A. Nelson, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full time	Part time	Full time	Part time
M.S. DEPARTMENTS[a]					
Fall 1982	131	494	310	1,075	1048
Fall 1983	132	452	293	1,098	981
Fall 1984	131	468	270	1,099	990
PH.D. DEPARTMENTS					
Fall 1982	189	3412	306	13,488	1483
Fall 1983	189	3554	275	14,037	1380
Fall 1984	186	3404	227	14,194	1314

a Departments whose highest offering is the master's degree in chemistry.

Chemistry and chemical engineering degrees awarded by approved schools, 1984–85

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	6	8	1	—	—	—	—
Adelphi U	3	6	2	—	—	—	—
Agnes Scott C	2	3	—	—	—	—	—
Akron, U of	16	2	5	4	a	—	—
Alabama, U of							
University	1	10	4	4	46	8	1
Birmingham	3	3	2	0	—	—	—
Huntsville	2	7	8	—	—	—	—
Alaska, U of	4	1	1	—	—	—	—
Albion C	1	11	—	—	—	—	—
Albright C	5	21	—	—	—	—	—
Alfred U	5	0	—	—	—	—	—
Allegheny C	1	17	—	—	—	—	—
Alma C	3	7	—	—	—	—	—
American U	5	3	4	11	—	—	—
Amherst C	0	13	—	—	—	—	—
Andrews U	5	8	—	—	—	—	—
Appalachian State U	3	6	0	—	—	—	—
Arizona State U	21	20	3	12	41	15	0
Arizona, U of	16	27	2	16	22	13	3
Arkansas, U of							
Fayetteville	3	7	1	5	46	14	4
Little Rock	2	5	2	—	—	—	—
Ashland C	2	1	—	—	—	—	—
Auburn U	4	28	8	2	75	9	1
Augsburg C	3	1	—	—	—	—	—
Augustana C (Illinois)	0	23	—	—	—	—	—
Augustana C (South Dakota)	2	4	—	—	—	—	—
Austin C	1	10	—	—	—	—	—
Baldwin-Wallace C	0	5	—	—	—	—	—
Ball State U	1	4	4	—	—	—	—
Barnard C	1	8	—	—	—	—	—
Bates C	4	10	—	—	—	—	—
Baylor U	4	11	0	2	—	—	—
Beloit C	3	9	—	—	—	—	—
Bemidji State U	2	9	—	—	—	—	—
Birmingham-Southern C	4	12	—	—	—	—	—
Bloomsburg U	4	0	—	—	—	—	—
Boston C	27	0	6	3	—	—	—
Boston U	1	16	4	6	—	—	—
Bowdoin C	1	27	—	—	—	—	—
Bowling Green State U	7	20	6	—	—	—	—
Bradley U	1	8	—	—	—	—	—
Brandeis U	0	13	9	5	—	—	—
Bridgeport, U of	4	1	0	—	—	—	—
Bridgewater State C	3	5	0	—	—	—	—
Brigham Young U	8	26	6	6	63	11	1
Brown U	0	14	0	16	—	—	—
Bryn Mawr C	15	0	1	1	—	—	—
Bucknell U	10	10	2	—	36	2	—
Butler U	5	15	7	—	—	—	—
California Institute of Tech	11	0	0	24	8	13	11
California Polytechnic State U	20	50	4	—	—	—	—
California State C							
Bakersfield	4	4	—	—	—	—	—
Stanislaus	1	5	—	—	—	—	—
California State Polytechnic U	5	4	3	—	a	—	—
California State U							
Chico	1	12	—	—	—	—	—
Dominguez Hills	4	6	—	—	—	—	—
Fresno	4	8	3	—	—	—	—
Fullerton	16	12	4	—	—	—	—
Hayward	6	13	1	—	—	—	—
Long Beach	8	16	4	—	75	—	—
Los Angeles	14	2	3	—	—	—	—
Northridge	12	7	3	—	—	—	—
Sacramento	9	10	5	—	—	—	—
San Bernardino	2	9	—	—	—	—	—
California, U of							
Berkeley	49	1	9	68	98	12	17
Davis	25	7	6	22	44	13	2
Irvine	10	46	6	13	—	—	—
Los Angeles	29	68	17	37	19	13	3
Riverside	7	3	4	13	—	—	—
San Diego	63	0	20	15	—	—	—
Santa Barbara	23	11	8	17	36	6	3
Santa Cruz	19	8	11	4	—	—	—
Calvin C	1	6	—	—	—	—	—
Canisius C	10	6	—	—	—	—	—
Capital U	1	5	—	—	—	—	—
Carleton C	2	33	—	—	—	—	—
Carnegie-Mellon U	26	0	7	4	57	9	13
Carroll C	5	9	—	—	—	—	—
Carthage C	3	2	—	—	—	—	—
Case Western Reserve U	4	33	7	12	51	11	3
Catholic U of America	0	0	1	3	a	—	—
Centenary C of Louisiana	0	0	—	—	—	—	—
Central C	0	5	—	—	—	—	—
Central Connecticut State U	4	1	0	—	—	—	—
Central Florida, U of	18	0	6	—	—	—	—
Central Michigan U	3	20	8	—	—	—	—
Central State U (Ohio)	0	3	—	—	—	—	—
Central State U (Oklahoma)	2	10	—	—	—	—	—
Centre C	0	1	—	—	—	—	—
Charleston, C of	12	10	—	—	—	—	—
Chatham C	0	4	—	—	—	—	—
Chestnut Hill C	6	5	—	—	—	—	—
Chicago, U of	9	30	4	16	—	—	—
Cincinnati, U of	30	0	13	24	64	10	1
Citadel, The	2	3	—	—	—	—	—
City U of New York							
Graduate Center	—	—	—	13	—	—	—
Brooklyn C	2	20	3	—	—	—	—
City C	5	15	1	—	39	8	3
Herbert H. Lehman C	4	9	—	—	—	—	—
Hunter C	4	6	—	—	—	—	—
Queens C	4	22	9	0	—	—	—
Clarion U of Pennsylvania	5	0	—	—	—	—	—
Clark U	6	0	0	0	—	—	—
Clarkson U	14	0	6	2	110	16	5
Clemson U	5	1	6	6	65	8	2
Cleveland State U	16	0	9	6	30	9	2
Coe C	0	5	—	—	—	—	—
Colby C	2	5	—	—	—	—	—
Colgate U	0	24	—	—	—	—	—
Colorado C	4	6	—	—	—	—	—
Colorado School of Mines	7	0	2	3	94	12	0
Colorado State U	8	5	3	16	32	7	0
Colorado, U of							
Boulder	13	40	8	17	65	15	4
Colorado Springs	5	6	—	—	—	—	—
Denver	4	9	0	—	—	—	—
Columbia U	6	6	26	18	44	29	6
Concordia C	4	2	—	—	—	—	—
Connecticut, U of	23	11	5	6	50	13	1
Cooper Union[b]	—	—	—	—	a	—	—
Cornell C	0	5	—	—	—	—	—
Cornell U	20	27	31	18	a	—	—
Creighton U	0	31	2	—	—	—	—
Dartmouth C	0	18	0	5	—	—	—
David Lipscomb C	1	11	—	—	—	—	—
Davidson C	5	2	—	—	—	—	—
Dayton, U of	9	9	1	—	42	7	—
Delaware State C	0	2	—	—	—	—	—
Delaware, U of	39	16	4	12	62	18	8
Delaware Valley C of Science & Agriculture	8	0	—	—	—	—	—
Delta State U	4	5	—	—	—	—	—
Denison U	1	6	—	—	—	—	—
Denver, U of	2	23	6	0	—	—	—
De Paul U	3	2	6	—	—	—	—
DePauw U	6	13	—	—	—	—	—
Detroit, U of	6	3	10	0	12	14	—
Dickinson C	1	15	—	—	—	—	—
Drake U	2	5	—	—	—	—	—
Drew U	1	10	—	—	—	—	—
Drexel U	10	0	14	3	78	12	1
Duke U	19	33	1	14	—	—	—
Duquesne U	1	4	1	1	—	—	—
Earlham C	3	7	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
East Carolina U	6	2	4	—	—	—	—
East Stroudsburg U	5	4	0	—	—	—	—
East Tennessee State U	4	9	1	—	—	—	—
East Texas State U	2	4	2	—	—	—	—
Eastern Illinois U	4	6	2	—	—	—	—
Eastern Kentucky U	6	16	3	—	—	—	—
Eastern Michigan U	4	37	6	—	—	—	—
Eastern New Mexico U	0	2	4	—	—	—	—
Eckerd C	4	1	—	—	—	—	—
Elizabethtown C	3	12	—	—	—	—	—
Elmhurst C	1	18	—	—	—	—	—
Emory U	1	82	4	13	—	—	—
Emporia State U	2	3	1	—	—	—	—
Evansville, U of	2	2	—	—	—	—	—
Fairfield U	7	1	—	—	—	—	—
Fairleigh Dickinson U							
Madison	7	0	3	—	—	—	—
Teaneck	19	1	6	—	—	—	—
Fisk U	10	0	1	—	—	—	—
Florida Atlantic U	9	16	—	—	—	—	—
Florida Institute of Tech	1	1	2	—	13	0	—
Florida International U	4	11	—	—	—	—	—
Florida State U	1	24	6	13	—	—	—
Florida, U of	8	41	7	20	59	21	10
Fordham U	0	17	2	—	—	—	—
Fort Lewis C	3	11	—	—	—	—	—
Franklin & Marshall C	10	12	—	—	—	—	—
Furman U	12	3	2	—	—	—	—
Geneva C	1	16	—	—	—	—	—
George Mason U	9	4	—	—	—	—	—
George Washington U	9	10	2	1	—	—	—
Georgetown U	21	0	3	4	—	—	—
Georgia Institute of Tech	15	0	4	13	165	20	2
Georgia State U	2	2	2	—	—	—	—
Georgia, U of	6	39	10	16	—	—	—
Gettysburg C	2	9	—	—	—	—	—
Glassboro State C	7	2	—	—	—	—	—
Gonzaga U	3	3	—	—	—	—	—
Goucher C	1	8	—	—	—	—	—
Grand Valley State C	1	10	—	—	—	—	—
Grinnell C	5	15	—	—	—	—	—
Gustavus Adolphus C	2	10	—	—	—	—	—
Hamilton C	0	5	—	—	—	—	—
Hamline U	9	2	—	—	—	—	—
Hampden-Sydney C	2	5	—	—	—	—	—
Hampton U	6	1	2	—	—	—	—
Hartford, U of	3	3	0	—	—	—	—
Hartwick C	4	5	—	—	—	—	—
Harvard U	0	24	11	20	—	—	—
Harvey Mudd C	16	0	—	—	—	—	—
Haverford C	1	7	—	—	—	—	—
Hawaii, U of	15	5	2	9	—	—	—
Hiram C	4	5	—	—	—	—	—
Hobart & William Smith C	1	4	—	—	—	—	—
Hofstra U	2	15	—	—	—	—	—
Hollins C	0	2	—	—	—	—	—
Holy Cross, C of the	22	12	—	—	—	—	—
Hope C	22	16	—	—	—	—	—
Houston, U of	17	2	10	15	40	35	6
Howard U	2	32	9	5	15	1	—
Humboldt State U	1	5	—	—	—	—	—
Idaho State U	2	4	0	—	—	—	—
Idaho, U of	5	4	2	3	21	8	2
Illinois Benedictine C	15	0	—	—	—	—	—
Illinois Institute of Tech	2	0	4	3	44	17	4
Illinois State U	31	0	11	—	—	—	—
Illinois, U of							
Chicago	19	19	19	9	40	18	0
Urbana-Champaign	63	39	12	56	98	20	22
Illinois Wesleyan U	3	3	—	—	—	—	—
Indiana State U	7	0	2	—	—	—	—
Indiana U							
Bloomington	29	120	11	26	—	—	—
South Bend	2	1	—	—	—	—	—
Indiana U of Pennsylvania	13	5	7	—	—	—	—
Indiana U-Purdue U							
Fort Wayne	6	6	—	—	—	—	—
Indianapolis	2	20	8	—	—	—	—
Iowa State U	11	6	4	35	73	12	5

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Iowa, U of	14	0	10	7	32	8	2
Ithaca C	5	7	—	—	—	—	—
Jackson State U	2	3	7	—	—	—	—
James Madison U	4	3	—	—	—	—	—
John Carroll C	4	15	0	—	—	—	—
Johns Hopkins U	24	0	9	9	14	4	0
Juniata C	2	13	—	—	—	—	—
Kalamazoo C	5	23	—	—	—	—	—
Kansas State U	6	5	7	9	28	5	2
Kansas, U of	20	29	4	8	32	11	1
Kean C of New Jersey	5	9	—	—	—	—	—
Kearney State C	2	5	—	—	—	—	—
Kent State U	11	9	1	3	—	—	—
Kentucky, U of	14	16	7	4	60	6	2
Kenyon C	5	4	—	—	—	—	—
King's C	3	3	—	—	—	—	—
Knox C	2	14	—	—	—	—	—
Lafayette C	4	13	—	—	37	—	—
Lake Forest C	0	9	—	—	—	—	—
Lamar U	9	2	0	—	26	19	3
La Salle C	4	2	—	—	—	—	—
Lawrence Institute of Tech	7	0	—	—	—	—	—
Lawrence U[c]	4	2	14	3	—	—	—
Lebanon Valley C	5	8	—	—	—	—	—
Lehigh U	8	0	12	12	66	37	3
Le Moyne C	4	2	—	—	—	—	—
Lincoln U	1	13	—	—	—	—	—
Long Island U							
Brooklyn Center	0	12	9	—	—	—	—
C. W. Post Campus	1	1	—	—	—	—	—
Loras C	0	2	—	—	—	—	—
Louisiana State U							
Baton Rouge	10	3	0	12	51	14	2
Shreveport	3	0	—	—	—	—	—
Louisiana Tech U	3	4	3	—	18	5	1
Louisville, U of	7	24	1	5	28	14	0
Lowell, U of	11	0	2	5	a	—	—
Loyola C	11	1	—	—	—	—	—
Loyola Marymount U	5	0	—	—	—	—	—
Loyola U (New Orleans)	1	1	—	—	—	—	—
Loyola U (Chicago)	18	9	6	5	—	—	—
Luther C	4	5	—	—	—	—	—
Macalester C	2	8	—	—	—	—	—
Maine, U of	5	3	4	0	48	6	3
Manhattan C[d]	11	3	—	—	67	35	—
Manhattanville C	2	1	—	—	—	—	—
Mankato State U	6	9	0	—	—	—	—
Marietta C	1	0	—	—	—	—	—
Marist C	0	1	—	—	—	—	—
Marquette U	14	0	1	4	—	—	—
Marshall U	3	17	1	—	—	—	—
Maryland, U of							
College Park	22	52	13	22	84	10	6
Baltimore County	14	0	4	—	—	—	—
Massachusetts Institute of Tech	25	0	1	39	102	55	27
Massachusetts, U of	8	10	8	17	46	10	14
McMurry C	0	2	—	—	—	—	—
McNeese State U	4	3	2	—	—	—	—
Memphis State U	2	6	0	0	—	—	—
Mercer U	7	3	—	—	—	—	—
Merrimack C	8	1	—	—	—	—	—
Metropolitan State C	7	8	—	—	—	—	—
Miami U	16	37	5	4	—	—	—
Miami, U of	3	96	0	1	—	—	—
Michigan State U	31	21	4	17	75	15	0
Michigan Technological U	20	0	1	3	81	5	0
Michigan, U of							
Ann Arbor	62	0	31	24	116	21	12
Dearborn	6	17	—	—	—	—	—
Flint	3	6	—	—	—	—	—
Middle Tennessee State U	0	21	4	—	—	—	—
Middlebury C	0	12	0	—	—	—	—
Midwestern State U	4	4	—	—	—	—	—
Millersville U	5	11	—	—	—	—	—
Millsaps C	1	21	—	—	—	—	—
Minnesota, U of							
Minneapolis	41	0	14	26	a	—	—
Duluth	9	12	5	—	—	—	—
Mississippi C	0	8	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Mississippi State U	1	2	3	4	59	5	0
Mississippi, U of	1	11	2	0	18	10	1
Missouri, U of							
Columbia	20	7	5	3	58	6	1
Kansas City	3	16	0	3	—	—	—
Rolla	10	0	5	5	109	10	1
St. Louis	10	11	4	2	—	—	—
Missouri Western State C	3	0	—	—	—	—	—
Monmouth C (Illinois)	0	7	—	—	—	—	—
Monmouth C (New Jersey)	3	0	—	—	—	—	—
Montana C of Mineral Science & Tech	3	1	2	—	—	—	—
Montana State U	3	6	4	5	80	6	0
Montana, U of	8	4	1	2	—	—	—
Montclair State C	1	14	8	—	—	—	—
Moorhead State U	2	5	—	—	—	—	—
Moravian C	3	2	—	—	—	—	—
Morehouse C[e]	0	5	7	2	—	—	—
Morgan State U	3	7	—	—	—	—	—
Mount Holyoke C	0	15	1	0	—	—	—
Mount Saint Vincent, C of[d]	0	1	—	—	—	—	—
Muhlenberg C	0	21	—	—	—	—	—
Murray State U	6	17	2	—	—	—	—
Muskingum C	1	2	—	—	—	—	—
Nebraska, U of							
Lincoln	0	15	3	8	21	10	0
Omaha	3	2	—	—	—	—	—
Nebraska Wesleyan U	3	4	—	—	—	—	—
Nevada, U of							
Las Vegas	1	3	—	—	—	—	—
Reno	2	0	1	1	—	—	—
New Hampshire, U of	10	9	4	6	25	8	1
New Jersey Institute of Tech[b]	—	—	—	—	81	21	5
New Mexico Highlands U	0	1	2	—	—	—	—
New Mexico Institute of Mining & Tech	12	0	2	—	—	—	—
New Mexico State U	6	11	4	8	21	7	—
New Mexico, U of	7	9	10	7	25	18	7
New Orleans, U of	1	7	1	4	—	—	—
New York U	8	48	14	11	—	—	—
Niagara U	2	9	—	—	—	—	—
North Alabama, U of	3	8	—	—	—	—	—
North Carolina A&T State U	1	0	3	—	—	—	—
North Carolina Central U	1	10	1	—	—	—	—
North Carolina State U	18	20	2	6	123	11	4
North Carolina, U of							
Asheville	4	2	—	—	—	—	—
Chapel Hill	34	80	5	22	—	—	—
Charlotte	3	6	1	—	—	—	—
Greensboro	5	5	4	—	—	—	—
Wilmington	4	8	—	—	—	—	—
North Dakota State U	0	21	4	1	—	—	—
North Dakota, U of	2	8	1	0	25	4	—
North Texas State U	4	8	7	8	—	—	—
Northeast Louisiana U	2	2	7	—	—	—	—
Northeastern Illinois U	0	8	3	—	—	—	—
Northeastern U	4	0	11	8	52	10	0
Northern Arizona U	6	19	0	—	—	—	—
Northern Colorado, U of	0	7	0	0	—	—	—
Northern Illinois U	12	9	5	3	—	—	—
Northern Iowa, U of	6	17	2	—	—	—	—
Northern Kentucky U	3	6	—	—	—	—	—
Northern Michigan U	0	5	0	—	—	—	—
Northwest Missouri State U	5	1	—	—	—	—	—
Northwestern State U of Louisiana	0	1	—	—	—	—	—
Northwestern U	20	15	16	22	a	—	—
Norwich U	0	0	—	—	—	—	—
Notre Dame, U of	8	11	6	7	65	12	10
Oakland U	1	1	2	—	—	—	—
Oberlin C	0	22	—	—	—	—	—
Occidental C	1	5	—	—	—	—	—
Ohio Northern U	4	5	—	—	—	—	—
Ohio State U	36	0	18	34	75	27	2
Ohio U	13	4	5	1	22	8	0
Ohio Wesleyan U	0	5	—	—	—	—	—
Oklahoma State U	2	4	1	6	40	22	6
Oklahoma, U of	10	26	16	6	33	21	3
Old Dominion U	7	2	9	—	—	—	—
Oregon State U	12	0	5	6	47	9	1
Oregon, U of	7	29	5	7	—	—	—
Pace U	1	3	—	—	—	—	—
Pacific Lutheran U	2	5	—	—	—	—	—
Pacific, U of the	2	7	3	0	—	—	—
Pennsylvania State U	5	37	5	31	164	16	3
Pennsylvania, U of	4	20	5	26	35	6	5
Philadelphia C of Pharmacy & Science	10	0	2	0	—	—	—
Philadelphia C of Textiles & Science	7	0	—	—	—	—	—
Pittsburg State U	7	2	3	—	—	—	—
Pittsburgh, U of	14	69	9	18	87	29	3
Polytechnic Institute of N.Y.	5	6	9	7	31	12	2
Pomona C	5	7	—	—	—	—	—
Portland State U	0	9	1	1	—	—	—
Pratt Institute[b]	—	—	—	—	7	—	—
Princeton U	27	9	14	20	33	3	14
Providence U	5	4	0	0	—	—	—
Puerto Rico, U of							
Mayaguez	27	1	7	—	77	5	—
Rio Piedras	20	53	5	6	—	—	—
Puget Sound, U of	4	5	—	—	—	—	—
Purdue U	30	22	14	46	148	14	10
Purdue U Calumet	5	2	—	—	—	—	—
Randolph-Macon Woman's C	3	1	—	—	—	—	—
Redlands, U of	1	1	—	—	—	—	—
Reed C	14	6	—	—	—	—	—
Regis C	0	1	—	—	—	—	—
Rensselaer Polytechnic Inst	20	0	25	14	73	14	1
Rhode Island, U of	5	1	2	3	a	—	—
Rhodes C	7	8	—	—	—	—	—
Rice U	17	1	8	7	26	4	8
Richmond, U of	0	16	1	—	—	—	—
Rider C	4	0	—	—	—	—	—
Ripon C	5	1	—	—	—	—	—
Roanoke C	2	9	—	—	—	—	—
Rochester Institute of Tech	16	5	6	—	—	—	—
Rochester, U of	15	0	25	15	52	22	2
Rollins C	4	1	—	—	—	—	—
Roosevelt U	7	5	7	—	—	—	—
Rose-Hulman Institute of Tech	6	0	—	—	a	—	—
Russell Sage C	4	0	—	—	—	—	—
Rutgers U							
New Brunswick	51	17	10	12	77	26	7
Camden C	0	10	—	—	—	—	—
Newark C of Arts & Sciences	10	15	14	2	—	—	—
Saginaw Valley State C	3	8	—	—	—	—	—
St. Anselm C	3	4	—	—	—	—	—
St. Catherine, C of	1	6	—	—	—	—	—
St. Cloud State U	1	11	—	—	—	—	—
St. John Fisher C	10	6	—	—	—	—	—
St. John's U	7	2	8	—	—	—	—
St. John's U/C of St. Benedict	6	11	—	—	—	—	—
St. Joseph C	2	5	6	—	—	—	—
St. Joseph's U	5	25	7	—	—	—	—
St. Lawrence U	3	18	—	—	—	—	—
St. Louis U	7	30	10	—	—	—	—
St. Mary's C	2	5	—	—	—	—	—
St. Michael's C	4	0	—	—	—	—	—
St. Olaf C	6	46	—	—	—	—	—
St. Peter's C	4	5	—	—	—	—	—
St. Thomas, C of	0	8	—	—	—	—	—
Salem State C	4	0	—	—	—	—	—
Sam Houston State U	6	2	5	—	—	—	—
San Diego State U	19	2	6	1	—	—	—
San Francisco State U	11	23	6	—	—	—	—
San Francisco, U of	2	6	4	—	—	—	—
San Jose State U	26	11	12	—	20	10	—
Sangamon State U	1	2	—	—	—	—	—
Santa Clara, U of	4	4	—	—	—	—	—
Scranton, U of	6	23	15	—	—	—	—
Seattle U	2	4	—	—	—	—	—
Seton Hall U	5	7	10	11	—	—	—
Shippensburg U	11	1	2	—	—	—	—
Siena C	11	0	—	—	—	—	—
Simmons C	1	1	—	—	—	—	—
Skidmore C	2	15	—	—	—	—	—
Smith C	13	0	0	0	—	—	—
Sonoma State U	3	19	—	—	—	—	—
South Carolina, U of	0	20	8	23	28	5	0

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
South Dakota School of Mines & Tech	5	0	5	—	36	6	—
South Dakota State U	4	20	4	—	—	—	—
South Dakota, U of	8	11	4	—	—	—	—
South Florida, U of	23	52	1	3	45	2	0
Southeast Missouri State U	2	6	—	—	—	—	—
Southeastern Louisiana U	0	2	—	—	—	—	—
Southeastern Massachusetts U	12	3	1	—	—	—	—
Southern California, U of	15	8	3	13	46	11	1
Southern Colorado U	1	9	—	—	—	—	—
Southern Illinois U							
Carbondale	7	8	2	9	—	—	—
Edwardsville	6	4	8	—	—	—	—
Southern Methodist U	4	3	1	—	—	—	—
Southern Mississippi, U of	2	17	3	2	—	—	—
Southern Oregon State C	7	1	—	—	—	—	—
Southern U & A&M C	2	2	1	—	—	—	—
Southwest Missouri State U	1	16	—	—	—	—	—
Southwest State U	3	5	—	—	—	—	—
Southwest Texas State U	11	3	8	—	—	—	—
Southwestern Louisiana, U of	0	6	2	—	a	—	—
Southwestern Oklahoma State U	4	6	—	—	—	—	—
Stanford U	9	17	3	19	14	26	9
State U of New York							
Albany	21	1	2	4	—	—	—
Binghamton	7	25	7	5	—	—	—
Buffalo	20	17	8	13	99	18	5
Stony Brook	25	31	3	17	—	—	—
C at Brockport	6	6	—	—	—	—	—
C at Buffalo	6	4	2	—	—	—	—
C at Cortland	3	6	—	—	—	—	—
C at Fredonia	9	10	1	—	—	—	—
C at Geneseo	8	0	0	—	—	—	—
C at New Paltz	8	1	0	—	—	—	—
C at Oneonta	1	20	0	—	—	—	—
C at Oswego	14	8	5	—	—	—	—
C at Plattsburgh	10	10	1	—	—	—	—
C at Potsdam	0	19	—	—	—	—	—
Stephen F. Austin State U	2	4	1	—			
Stetson U	5	4	—	—	—	—	—
Stevens Institute of Tech	5	4	8	1	—	—	—
Suffolk U	2	2	—	—	—	—	—
Susquehanna U	3	2	—	—	—	—	—
Swarthmore C	7	10	—	—	—	—	—
Syracuse U	10	7	0	4	20	14	0
Temple U	8	12	1	7	—	—	—
Tennessee Technological U	3	12	1	—	35	6	0
Tennessee, U of							
Knoxville	4	16	2	8	91	13	5
Martin	3	7	—	—	—	—	—
Chattanooga	16	13	—	—	—	—	—
Texas A&I U	3	0	3	—	13	4	—
Texas A&M U	22	9	11	22	123	23	3
Texas Christian U	3	13	2	2	—	—	—
Texas Southern U	10	0	6	—	—	—	—
Texas Technological U	12	16	9	4	42	10	3
Texas, U of							
Arlington	12	6	4	0	—	—	—
Austin	42	0	8	28	115	26	17
Dallas	8	1	9	—	—	—	—
El Paso	8	0	8	—	—	—	—
Texas Woman's U	0	9	0	2	—	—	—
Thiel C	2	2	—	—	—	—	—
Thomas More C	1	1	—	—	—	—	—
Toledo, U of	5	11	3	2	24	8	1
Towson State U	3	8	—	—	—	—	—
Trenton State C	13	0	—	—	—	—	—
Trinity C	10	5	0	—	—	—	—
Trinity U	1	7	—	—	—	—	—
Tri-State U[b]	—	—	—	—	22	—	—
Tufts U	0	14	2	5	41	12	0
Tulane U of Louisiana	1	4	1	2	28	4	1
Tulsa, U of	2	0	—	—	31	9	2
Tuskegee U	0	4	0	—	8	—	—
Union C	4	12	—	—	—	—	—
U.S. Air Force Academy	8	5	—	—	—	—	—
U.S. Naval Academy	20	1	—	—	—	—	—
Ursinus C	6	22	—	—	—	—	—
Utah State U	2	0	1	1	—	—	—
Utah, U of	8	32	1	16	39	0	1
Valparaiso U	6	35	—	—	—	—	—
Vanderbilt U	3	16	5	8	43	5	1
Vassar C	2	6	2	—	—	—	—
Vermont, U of	22	0	0	7	—	—	—
Villanova U	10	0	12	6	39	14	—
Virginia Commonwealth U	10	9	2	3	—	—	—
Virginia Military Institute	9	0	—	—	—	—	—
Virginia Polytechnic Institute & State U	18	11	12	13	82	17	6
Virginia, U of	12	73	6	4	37	27	3
Wabash C	2	7	—	—	—	—	—
Wagner C	0	4	—	—	—	—	—
Wake Forest U	9	17	2	0	—	—	—
Washburn U of Topeka	2	1	—	—	—	—	—
Washington C	6	0	—	—	—	—	—
Washington & Jefferson C	4	31	—	—	—	—	—
Washington & Lee U	0	9	—	—	—	—	—
Washington State U	9	12	5	15	32	5	2
Washington U	6	14	8	9	45	8	6
Washington, U of	40	16	22	16	67	14	4
Wayne State U	26	29	7	11	57	21	2
Waynesburg C	0	4	—	—	—	—	—
Weber State C	3	5	—	—	—	—	—
Wellesley C	7	22	—	—	—	—	—
Wesleyan U	4	19	1	4	—	—	—
West Chester U	5	5	5	—	—	—	—
West Florida, U of	6	5	—	—	—	—	—
West Texas State U	3	13	2	—	—	—	—
West Virginia Institute of Tech	3	0	—	—	19	2	—
West Virginia State C	1	3	—	—	—	—	—
West Virginia U	7	36	9	5	48	4	0
Western Illinois U	4	7	2	—	—	—	—
Western Kentucky U	6	10	3	—	—	—	—
Western Maryland C	1	7	—	—	—	—	—
Western Michigan U	3	13	7	1	—	—	—
Western New England C	3	0	—	—	—	—	—
Western Washington U	17	5	2	—	—	—	—
Westminster C	0	3	—	—	—	—	—
Wheaton C (Illinois)	1	14	—	—	—	—	—
Wheaton C (Massachusetts)	5	6	—	—	—	—	—
Wheeling C	0	2	—	—	—	—	—
Whitman C	6	9	—	—	—	—	—
Whittier C	1	4	—	—	—	—	—
Wichita State U	7	11	2	—	—	—	—
Widener U	0	4	—	—	—	—	—
Wilkes C	2	2	—	—	—	—	—
Willamette U	1	11	—	—	—	—	—
William Paterson C of N.J.	3	0	—	—	—	—	—
William & Mary, C of	38	5	9	—	—	—	—
Williams C	2	35	—	—	—	—	—
Wisconsin, U of							
Eau Claire	2	12	—	—	—	—	—
Green Bay	0	5	—	—	—	—	—
La Crosse	1	14	—	—	—	—	—
Madison	17	30	10	39	119	11	23
Milwaukee	3	20	9	3	—	—	—
Oshkosh	6	4	—	—	—	—	—
Parkside	3	8	—	—	—	—	—
Platteville	0	3	—	—	—	—	—
River Falls	7	12	—	—	—	—	—
Stevens Point	7	7	—	—	—	—	—
Superior	2	2	—	—	—	—	—
Wittenberg U	3	5	—	—	—	—	—
Wooster, C of	1	27	—	—	—	—	—
Worcester Polytechnic Institute	3	5	1	1	48	13	2
Wright State U	12	6	6	—	—	—	—
Wyoming, U of	0	6	4	5	14	6	0
Xavier U	2	11	5	—	—	—	—
Xavier U of Louisiana	1	20	—	—	—	—	—
Yale U	7	0	22	11	a	—	—
Youngstown State U	3	31	5	—	a	—	—
TOTALS	4021	5658	1621	1806	6442	1489	418

a Data not submitted. b Listed on basis of accreditation by AIChE-ABET. c Master's and Ph.D. degrees given by the Institute of Paper Chemistry. d The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College. e Master's and Ph.D. degrees given by Atlanta University. Note: For brevity, B.S. and M.S. are used to denote all bachelor's and master's degrees, respectively, in each column.

Indiana new leader of graduate listing

Indiana University produced more new bachelor chemistry graduates (149) during the 1984–85 academic year than any other school in the country. Cornell University and the University of Michigan shared the lead among producers of new chemistry graduates at the masters level, each with 31. And the University of California, Berkeley, had the most new doctoral chemistry graduates with 68.

These are some of the highlights that can be gleaned from the latest report of ACS's Committee on Professional Training. The full report starts on page 43 of this issue. The committee is charged with setting standards for undergraduate programs and for monitoring them. And on an annual basis, the committee gathers statistics on new graduates at all levels from the departments it approves.

Indiana moved up from the second spot it held the previous four years to top the list of producers of new chemistry bachelor graduates in the current report. Illinois, Urbana-Champaign, the previous leader, moved down to third. And second on the new list is North Carolina, Chapel Hill, a school that topped the list in nine of the previous 11 years.

In the new report, the University of California, San Diego, and Illinois, Urbana-Champaign, share the lead among producers of new bachelor chemists with degrees certified by ACS. San Diego headed this list for the eight years ending 1980–81. Certified graduates are immediately eligible for ACS membership.

The coleaders in production of new masters chemists had both topped the list in recent years—Michigan in 1983–84 and Cornell in 1982–83.

For the past 12 years either Illinois, Urbana-Champaign (eight times), or California, Berkeley (four times), has been the largest producer of new doctoral chemists. In 1984–85 it was Berkeley's turn with Illinois second. Third was Purdue University, which moved up from ninth in 1983–84. □

These schools had the most chemistry graduates, 1984–85

Total bachelor graduates	
1. Indiana U	149
2. U of North Carolina, Chapel Hill	114
3. U of Illinois, Urbana-Champaign	102
4. U of Miami	99
5. U of California, Los Angeles	97
6. U of Virginia	85
7. Emory U	83
7. U of Pittsburgh	83
9. U of South Florida	75
10. U of Maryland, College Park	74
11. U of Puerto Rico	73
12. California Polytechnic State U	70
13. Rutgers U	68
14. U of California, San Diego	63
15. U of Michigan	62
16. U of California, Irvine	56
16. New York U	56
16. State U of New York, Stony Brook	56
16. U of Washington	56
20. U of Delaware	55
20. Wayne State U	55
22. U of Colorado	53
22. Miami U	53
24. Duke U	52
24. Michigan State U	52
24. Purdue U	52
24. St. Olaf C	52

Certified bachelor graduates	
1. U of California, San Diego	63
2. U of Illinois, Urbana-Champaign	63
3. U of Michigan	62
4. Rutgers U	51
5. U of California, Berkeley	49
6. U of Texas	42
7. U of Minnesota	41
8. U of Washington	40
9. U of Delaware	39
10. C of William & Mary	38
11. Ohio State U	36
12. U of North Carolina, Chapel Hill	34
13. Illinois State U	31
13. Michigan State U	31
15. U of Cincinnati	30
15. Purdue U	30
17. U of California, Los Angeles	29
17. Indiana U	29
19. Boston C	27
19. Princeton U	27
19. U of Puerto Rico, Mayaguez	27
22. Carnegie-Mellon U	26
22. San Jose State U	26
22. Wayne State U	26
25. U of California, Davis	25
25. Massachusetts Inst of Tech	25
25. State U of New York, Stony Brook	25

Masters graduates	
1. Cornell U	31
1. U of Michigan	31
3. Columbia U	26
4. Rensselaer Polytechnic Inst	25
4. U of Rochester	25
6. U of Washington	22
6. Yale U	22
8. U of California, San Diego	20
9. U of Illinois, Chicago	19
10. Ohio State U	18
11. U of California, Los Angeles	17
12. Northwestern U	16
12. U of Oklahoma	16
14. U of Scranton	15
15. Drexel U	14
15. Lawrence U[a]	14
15. U of Minnesota	14
15. New York U	14
15. Princeton U	14
15. Purdue U	14
15. Rutgers U, Newark C	14
22. U of Cincinnati	13
22. U of Maryland, College Park	13
24. U of Illinois, Urbana-Champaign	12
24. Lehigh U	12
24. San Jose State U	12
24. Villanova U	12
24. Virginia Polytechnic Inst	12

Doctoral graduates	
1. U of California, Berkeley	68
2. U of Illinois, Urbana-Champaign	56
3. Purdue U	46
4. Massachusetts Inst of Tech	39
4. U of Wisconsin, Madison	39
6. U of California, Los Angeles	37
7. Iowa State U	35
8. Ohio State U	34
9. Pennsylvania State U	31
10. U of Texas, Austin	28
11. Indiana U	26
11. U of Minnesota, Minneapolis	26
11. U of Pennsylvania	26
14. California Inst of Tech	24
14. U of Cincinnati	24
14. U of Michigan	24
17. U of South Carolina	23
18. U of California, Davis	22
18. U of Maryland, College Park	22
18. U of North Carolina, Chapel Hill	22
18. Northwestern U	22
18. Texas A&M U	22
23. U of Florida	20
23. Harvard U	20
23. Princeton U	20

[a] Degrees given by the Institute of Paper Chemistry.

NOTE

ONLY THE FOLLOWING PAGES OF THIS

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CHEMICAL & ENGINEERING

NEWS

George Keyworth reflects on science advisory role
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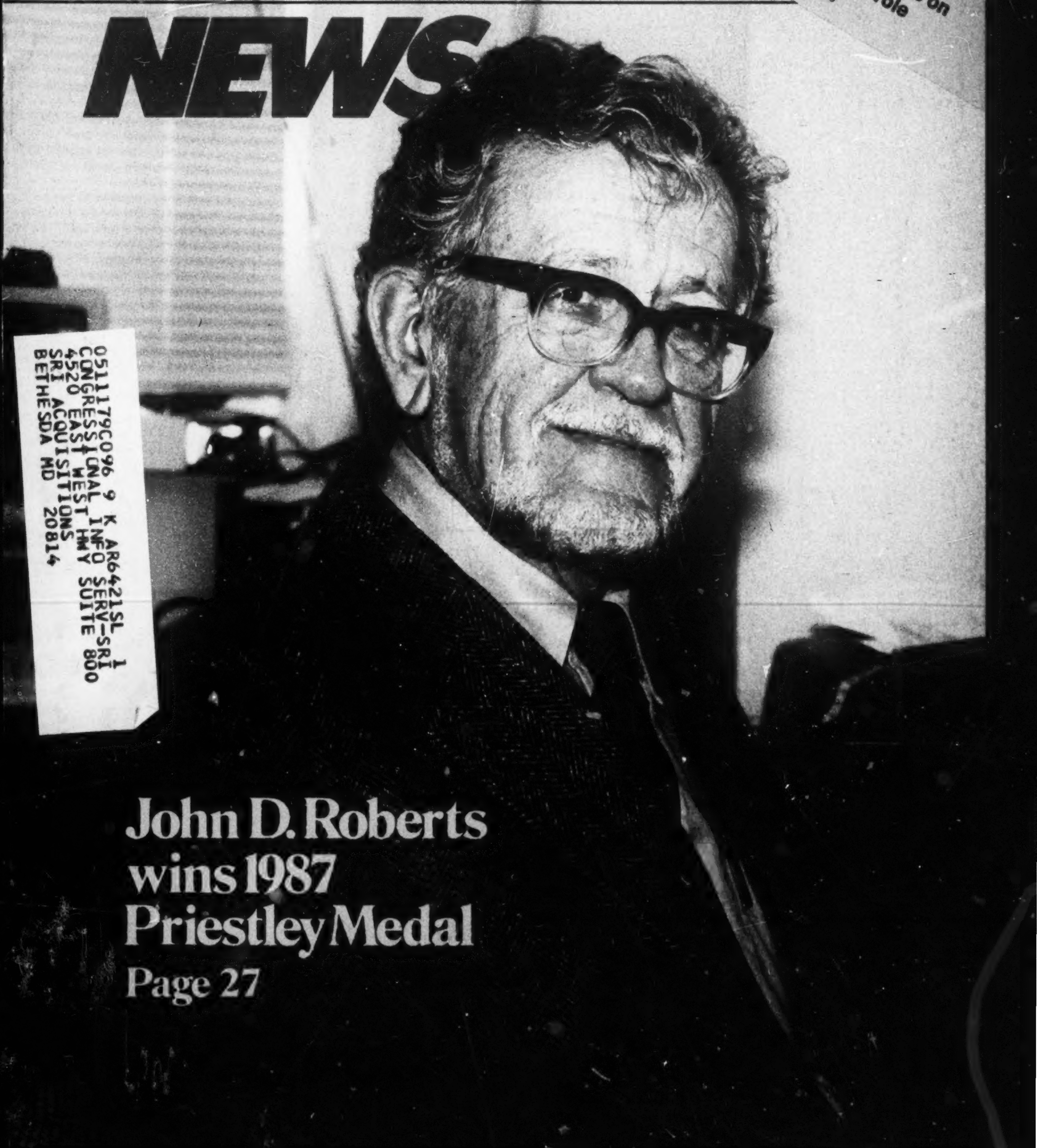

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John D. Roberts wins 1987 Priestley Medal

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CHEMICAL & ENGINEERING NEWS

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MAY 26, 1986

News of the Week

- **NRC's Space Science Board calls for diversification of space effort, including return to use of unmanned vehicles.** Page 4
- **Commerce's International Trade Administration proposes new rules governing export of scientific and technical data.** Page 5
- **Supreme Court rules EPA's aerial photographing of Dow plant was legal.** Page 5
- **Researchers find evidence that antibodies can be developed against certain core proteins produced by the virus that causes AIDS.** Page 5
- **Joint venture of Occidental Petroleum and Drexal Burnham Lambert to buy Diamond Shamrock Chemicals.** Page 6
- **EPA defers action on Monsanto request to field-test genetically engineered microbial pesticides, asks for more data.** Page 6

Cover: Photo by C&EN's Rudy M. Baum

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Business

Economist Charles Reeder forecasts export expansion and increase in industry operating rates leading to higher profits. **Page 15**

U.S. pharmaceutical firms had higher sales and profits thanks to the weakening of the dollar against foreign currencies. **Page 17**

The catalyst business, growing at a slow 3%-a-year pace, is by no means mature, rather is on the lookout for new markets. **Page 18**

Higher demand for pulp and paper and new technologies will boost the need for both new and different chemicals in papermaking. **Page 19**

Government

White House science council panel recommends increasing federal funds for academic research, hurt by 1970s cutback. **Page 23**

General Accounting Office faults EPA for haphazard overseeing of cleanup of hazardous waste sites by responsible parties. **Page 24**

Priestley Medal

John D. Roberts of Caltech, known for work with nuclear magnetic resonance spectroscopy, is 1987 Priestley Medalist. **Page 27**

Education

Lab course to bring high school chemistry teachers up to date on instrumentation is financed by Union Carbide. **Page 30**

News Focus

Former Presidential Science Adviser George Keyworth discusses his tenure at the Reagan White House, Strategic Defense Initiative. **Page 7**

Pharmaceutical earnings aided by weaker dollar

The weakening of the U.S. dollar against other currencies helped U.S. pharmaceutical and medical supply firms record strong increases in sales and net income in the first quarter of 1986. For many companies, more favorable exchange rates, along with increases in sales volume, translated into greater growth in sales revenues overseas than in the U.S.

A group of 16 companies, most of which depend on foreign sales for a large percentage of their revenues, reported a composite gain of 15% in after-tax earnings for the first quarter on a 17% rise in sales, compared with last year's first quarter. The group's composite profit margin (after-tax income as a percentage of sales) fell slightly to 12.1% from 12.4% in first-quarter 1985.

Net income rose most sharply at Becton Dickinson, up 41% (before an extraordinary tax credit) on an 11% increase in sales. The greatest share of the sales rise occurred overseas, where revenues increased $19 million, or 27%. The revitalization of local currencies against the dollar had a clear impact: Some $15 million of the international area's sales increase resulted from more favorable exchange rates. And the new situation also had its effect on the bottom line. Net income was about 16% higher than it would have been had the dollar remained at year-earlier exchange rates.

The weaker dollar also helped Squibb record a 23% increase in sales. Sales for the company's largest business segment, the pharmaceutical products group, rose 26%, but would have been up 23% if not for the change in exchange rates. Similarly, sales for the second-largest segment, medical products, increased 33%, but would have been up 27% without the more favorable rates. The company's personal care products group turned in a 9% sales gain. The increase would have been just 3% at year-earlier dollar values. Squibb's net income grew 27% in the first quarter, the second best gain in the 16-company group.

For Baxter Travenol, which acquired American Hospital Supply late last year, net income rose 26% on a 168% jump in sales. Much of that sales increase stems from the recent merger; first-quarter 1985 results were not restated to reflect it. Chief executive officer Vernon R. Loucks Jr. says the acquisition, which greatly expanded the company's range of products, was instrumental in enabling the company to prosper in a hospital supply market still characterized by strong cost-containment measures on the part of customers. The weaker dollar also helped Baxter Travenol. According to the company, nearly 10% of its $259 million in international sales in the first quarter was due to more favorable exchange rates.

Drug industry income rose 15% in first quarter

	Sales	Earnings[a]	Change from 1985		Profit margin[b]	
	($ millions)		Sales	Earnings	1986	1985
Abbott Labs	$ 865.5	$123.5	14%	21%	14.3%	13.5%
American Home Products	1264.7	196.9	5	9	15.6	15.0
Avon Products	608.5	15.7	15	15	2.6	2.6
Baxter Travenol	1367.0	49.0	168	26	3.6	7.6
Becton Dickinson	319.1	31.1	11	41	9.8	7.7
Bristol-Myers	1194.5	144.6	10	18	12.1	11.4
Lilly	988.3	172.6	9	7	17.5	17.7
Merck	921.1	157.8	8	20	17.1	15.4
Pfizer	1032.1	168.9	8	15	16.4	15.5
A. H. Robins	191.4	23.2	15	8	12.1	12.9
Schering-Plough	562.3	65.0	15	20	11.6	11.1
SmithKline Beckman	863.1	145.3	12	10	16.8	17.1
Squibb	558.9	53.6	23	27	9.6	9.3
Sterling Drug	420.2	35.4	7	11	8.4	8.1
Upjohn	537.4	63.0	13	15	11.7	11.5
Warner-Lambert	746.9	65.1	−6	9	8.7	7.5

a Excludes significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales.

At Schering-Plough, net income increased 20% on a 15% sales rise. The chief reason was growth in sales volume, according to Robert P. Luciano, chairman and chief executive officer. The gains were led by the U.S. pharmaceutical business, the international pharmaceutical operation—particularly in Europe and Latin America—and the sun care line.

Merck reported a 20% rise in net income. More favorable exchange rates boosted revenues 8% higher than they would have been at last year's dollar value (sales outside the U.S. accounted for 46% of all first-quarter sales), and sales volume increases were achieved in many product lines. Sales increased just 8% overall, however, because first-quarter 1985 figures include results for two subsidiaries, Calgon Carbon and Baltimore Aircoil, that were divested in second-quarter 1985.

Bristol-Myers' net earnings rose 18% on a 10% increase in sales. Through a restatement of first-quarter 1985 results, those figures account for the first-quarter 1986 acquisition of the Seattle biotechnology company, Genetic Systems. Like many other companies in the group, Bristol-Myers reported a greater gain in sales overseas, up 17%, than in the U.S., up 8%, during the first quarter.

Pfizer's net income increased 15% on an 8% rise in sales. The results, which are restated for first-quarter 1985 to reflect the May 1985 acquisition of American Medical Systems, were helped by currency exchange rates. Sales would have grown only 5% at the dollar's level a year earlier. Pharmaceutical sales, for example, increased 5% in the U.S. but 18% overseas. Pfizer recorded sales gains in health care, up 12%; specialty chemicals, up 6%; materials science, up 6%; and consumer products, up 5%. The company's agriculture segment, however, reported a 7% decline in sales.

David Webber, New York

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NEWS

Testing Employees For Illegal Drugs

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NEWS

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News of the Week

- **Higher gasoline demand pushes up aromatics prices but price tags on olefins remain low.** **Page 4**
- **High turnover rate of Presidential science advisers leads some to think that OSTP is of little concern to the Administration.** **Page 5**
- **Concerns about research funding during the budget-cutting era expressed by scientists attending the AAAS meeting.** **Page 5**
- **EPA nixes research burning of chemical wastes at sea.** **Page 6**
- **Evidence for presence of seventh AIDS virus gene discovered by Boston researchers.** **Page 6**

Cover: Thin-layer chromatogram used to detect illegal drugs in urine at American Medical Laboratories, Fairfax, Va. Photo by C&EN's David J. Hanson

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Business

Product sales accounted for a bigger share of biotechnology firms' revenues in the first quarter; many publicly owned companies sold new issues of common stock, fattening bank balances. **Page 17**

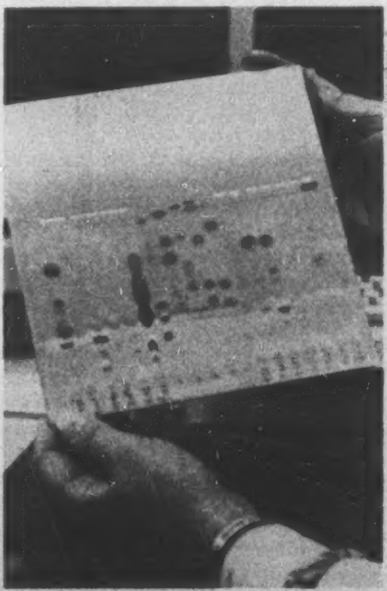
Government

Congress-passed bill to strengthen Safe Drinking Water Act places emphasis on groundwater protection, calls for EPA to set maximum permissible levels for 83 water contaminants. **Page 20**

Science

Hypervalent organic polyhalogens prepared by reacting fluorinated carbanions with fluorinated organoiodine compounds. **Page 22**

Catalytic asymmetric epoxidation of allylic alcohols may speed up industrial use of the reaction to make optically pure intermediates for drugs and pheromones. **Page 24**



News Focus

Although critics say the tests are inaccurate, and perhaps illegal, many companies are checking their employees for illicit drug use, using labs with sophisticated instrumentation. **Page 7**

Product Sales Highlight First-Quarter Biotechnology Results

Biotechnology companies bring more products to market, bolster cash assets through secondary stock offerings

David Webber, C&EN New York

Biotechnology companies freshened their bank balances, negotiated more lucrative deals with large corporations, and recorded more substantial product sales in the first part of 1986. As a result, more firms reported net income during the first quarter, and others, though still recording deficits, managed to narrow their losses from what they were a year earlier. Many publicly owned biotechnology companies also took advantage of the vigorous performance of the stock market during this period to sell new issues of common stock, thus netting large amounts of cash.

The first quarter was a tremendously successful one for Genentech, South San Francisco, Calif., the industry pacesetter. Not only did total revenues increase 44% from last year's first quarter to $29 million, but sales rose to $7.3 million from zero the year before. Product sales accounted for 25% of total revenues in the quarter. Contract revenues rose 4% and interest revenues increased 72%. Net income swelled 145% to $1.8 million.

All the company's product sales came from Protropin human growth hormone, which had revenues of $5.2 million when the product was introduced in fourth-quarter 1985. The company is moving rapidly to bring other products to market. In April, Genentech submitted to the Food & Drug Administration a product license application (the biologic equivalent of a new drug application) for its Activase tissue plasminogen activator. Earlier, the British patent office issued the company a patent on the product. Genentech also has moved a second-generation version of Protropin into Phase II clinical trials.

Cetus, Emeryville, Calif., boosted earnings to $360,400 on $15 million in revenues, a 19% increase from the year-earlier quarter. Most of the gain was due to payments from Eastman Kodak, which formed a venture with Cetus to develop human diagnostic products. Product sales remain small: $435,000, just 3% of total revenues. The company, which is spending heavily on clinical trials for its Proleukin human recombinant interleukin-2, on testing of other products, and on developing generic anticancer products in a joint venture with Ben Venue Laboratories, bolstered its bank account with a public stock offering during the quarter. As a result, Cetus had cash and short-term investments worth about $130 million at the end of the quarter.

Amgen, Thousand Oaks, Calif., boosted revenues 105% to $6.9 million, recording a $205,000 net profit after a $1.7 million loss in the same quarter a year earlier. The quarter, the fourth in Amgen's fiscal year, was the third straight in which the company was profitable.

During the quarter, Amgen established commercial relationships with Eastman Kodak to develop specialty chemicals and with SmithKline Beckman to develop animal health care products. With Beckman, the company will jointly develop and commercialize porcine somatropin, a growth regulator in pigs. The two companies will share costs and profits.

More biotechnology firms report net income

	FIRST-QUARTER 1986[a]					
	Revenues[b]	Earnings[c]	Change from 1985		Profit margin[d]	
	($ millions)		Revenues	Earnings	1986	1985
Amgen	$ 6.869	$ 0.205	105%	nm	3.0%	def
Applied Biosystems	15.216	2.654	45	37%	17.4	18.5%
Biogen	3.822	−6.267	−21	def	def	def
Bio-Response	0.224	−1.442	−60	def	def	def
BioTechnica International	1.788	−0.921	62	def	def	def
California Biotechnology	3.244	−0.150	63	def	def	def
Centocor	7.300	1.153	63	356	15.8	5.6
Cetus	15.002	0.360	19	71	2.4	1.7
Damon Biotech	0.837	−2.788	24	def	def	def
DNA Plant Technology	1.307	−0.042	38	def	def	def
Genentech	29.042	1.753	44	145	6.0	3.5
Immunex	1.300	−0.847	113	def	def	def
Molecular Genetics	2.762	0.012	18	nm	0.4	def
Monoclonal Antibodies	2.552	0.181	67	def	7.1	def
Ribi ImmunoChem	0.394	−0.035	145	def	def	def

a For three-month period ending closest to March 31. b Includes sales, contract research, royalty, and interest revenues. c Excludes extraordinary credits and nonrecurring items. d After-tax income as a percentage of sales. def = deficit. nm = not meaningful.

Sales account for larger share of revenues in first quarter

	Product sales ($ millions)	% change from 1985	Sales as % of total revenues	
			1986	1985
Amgen	$ 0.31	241%	5%	3%
Applied Biosystems	13.41	43	88	90
Biogen	0.00	nm	0	0
Bio-Response	0.00	nm	0	0
BioTechnica International	0.00	nm	0	0
California Biotechnology	0.00	nm	0	0
Centocor	na	nm	nm	nm
Cetus	0.44	76	3	2
Damon Biotech	na	nm	nm	nm
DNA Plant Technology	0.00	nm	0	0
Genentech	7.31	nm	25	0
Immunex	0.00	nm	0	0
Molecular Genetics	0.52	−10	19	25
Monoclonal Antibodies	2.22	80	87	81
Ribi ImmunoChem	0.11	36	28	50

nm = not meaningful. na = not available.

Amgen also shored up its asset base through a private sale of $5 million in common stock to SmithKline Beckman and a public sale of $37 million in common stock. At the end of March, the company's current assets stood at $69.8 million, compared with $23.7 million at the close of fiscal 1985.

Centocor, Malvern, Pa., increased revenues 63% to $7.3 million and net income (before an extraordinary credit) 356% to $1.2 million. Earlier this month, FMC Corp. withdrew a lawsuit it had filed against Centocor that sought damages and an extension of a deadline on Centocor's offer to buy FMC's interest in Immunorex, a 50-50 joint venture of the two firms. The venture, under which Centocor recorded 21% of its 1985 revenues, has been developing a product to treat gram-negative bacterial infections and is carrying out other research in human monoclonal antibodies and immunoregulation. As allowed by the joint venture agreement, Centocor offered to buy FMC's stake in February. The two companies are expected to negotiate out of court.

Biogen, of Geneva, Switzerland, and Cambridge, Mass., which is refocusing its business plan and reshaping its staff, reported a decline of 21% in revenues to $3.8 million. The company lost $6.3 million in the quarter, compared with a $5 million deficit a year earlier. Biogen has been looking for more advantageous licensing arrangements and has been cutting costs since the arrival of its new chairman, James Vincent, earlier this year.

"The first-quarter results reflect our decision to seek licensing arrangements that take into account the higher added value of our products," Vincent says. "We anticipate this new licensing strategy will result in more positive financial performance during the second half of this year. Operating expenses, which are down from the fourth quarter of 1985, remain under tight control."

During the first quarter, Biogen received a West German patent on gamma interferon for the treatment of rheumatoid arthritis. In early tests, the substance exhibited good anti-inflammatory properties. Also in the first quarter, the U.K. approved the marketing of Biogen's Intron A alpha interferon. The product will be marketed by Biogen's licensee, Schering-Plough. Ten countries have approved the sale of Intron A for a variety of cancers and viral infections.

California Biotechnology, Mountain View, Calif., raised revenues 63% to $3.2 million in first-quarter 1986. The quarter's loss totaled $150,000, compared with a deficit of $109,000 the year before. R&D contract revenue increased 24% to $2.2 million, and interest rose 386% to more than $1 million. At the same time, the company greatly increased its spending on proprietary research to $1.2 million from just $327,000 in the comparable quarter a year earlier. Primarily for that reason, total costs and expenses jumped 78% to $3.7 million.

"During the remainder of 1986, we expect to close additional licensing agreements for Cal Bio products and increase interest income to offset these increased research expenditures, resulting in a profitable year," says William G. Baker Jr., chairman and chief executive officer.

The company's financial underpinnings have already been improved by the March 26 public sale of common stock, which netted the company $60.9 million. The receipts, which were not recorded in the first quarter, will greatly bolster California Biotechnology's balance of cash and marketables, which stood at $18.6 million at the close of the first quarter, down from $22 million 12 months earlier.

Molecular Genetics, Minnetonka, Minn., reported a small profit on an 18% increase in revenues. Research revenues grew 24%, thanks largely to the receipt of an advance royalty payment from Terra International. In March, Molecular Genetics formed a joint venture seed company with Terra to develop enhanced varieties of corn seed. Molecular Genetics continues to have trouble increasing sales of its monoclonal antibody for the treatment of calf scours because of the depressed farm economy. Product sales in the quarter totaled $518,968, down from $575,268 in the year-earlier period. The company, also seeking to cash in on the stock market's current love affair with biotechnology stocks, filed May 6 for an offering of 1.5 million shares of common stock.

Damon Biotech, Needham Heights, Mass., narrowed its loss in its second fiscal quarter, which ended Feb. 28, to $2.8 million from a deficit of $3 million in the comparable period in 1985 (both before a federal income tax benefit). Total revenues rose 24% to $837,584.

During the quarter, Damon Biotech netted $16 million in a secondary offering of its common stock. □

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JUNE 9, 1986

CHEMICAL & ENGINEERING NEWS

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- **FDA approves U.S. marketing of alpha interferon for combating hairy cell leukemia.** Page 7
- **ACS president George Pimentel receives Robert A. Welch Award in chemistry.** Page 7
- **Agracetus is field-testing genetically engineered, disease-resistant tobacco but testing of bacteria preventing frost damage postponed again.** Page 8
- **William R. Graham has been appointed Presidential science adviser.** Page 8

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Government

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Science

Porphycene, a porphin isomer, may be the forerunner of a new series of porphynoid species. **Page 27**

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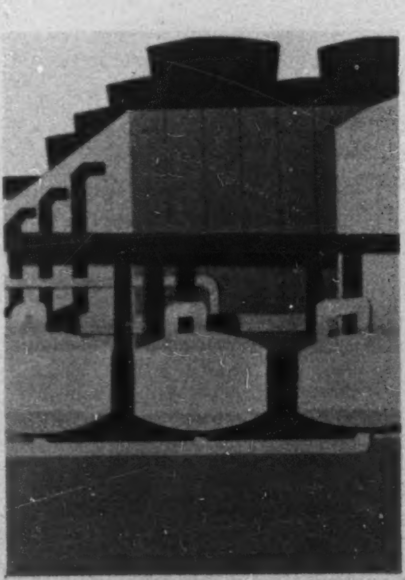
"Chemistry in America, 1876–1976: Historical Indicators" is an outstanding volume of information, ideas, speculation. **Page 91**

ACS News

Allocations to local sections and to C&EN will increase with the rise in membership dues for 1987. **Page 98**



Facts & Figures

The U.S. chemical industry showed moderate growth in 1985, but much restructuring and other efficiency moves affected profits. C&EN's yearly survey of the industry here and abroad identifies the major trends. **Page 32**

Petrochemical Selling Prices and Margins Shrink as Volume Increases

Profits in ethylene, propylene, butadiene, benzene, and *p*-xylene are unlikely to improve this year for major producers

Bruce F. Greek, C&EN Houston

Despite increased output of many petrochemicals, producers are seeing their margins shrink. Profits grew early in 1986 as prices of crude oil, its products, and other feedstocks for making petrochemicals declined much faster than did selling prices of petrochemicals. But now, selling prices for many olefins are weakening, and feedstock prices have begun to rise rapidly. When earnings figures for 1986 are complete, petrochemical profits will be better than in several years, yet not so good as would be expected, considering the decline in feedstock and other costs.

The volatility in feedstock prices and, to a lesser degree, in petrochemical selling prices almost ended meaningful planning this spring. Even now, forecasts for costs, volumes, and prices of petrochemicals must be changed often as feedstock prices change. This "shoot-from-the-hip" situation probably won't end until sometime next year when oil prices stabilize.

In the past, feedstock and selling prices have been volatile, but never so volatile as they were this year.

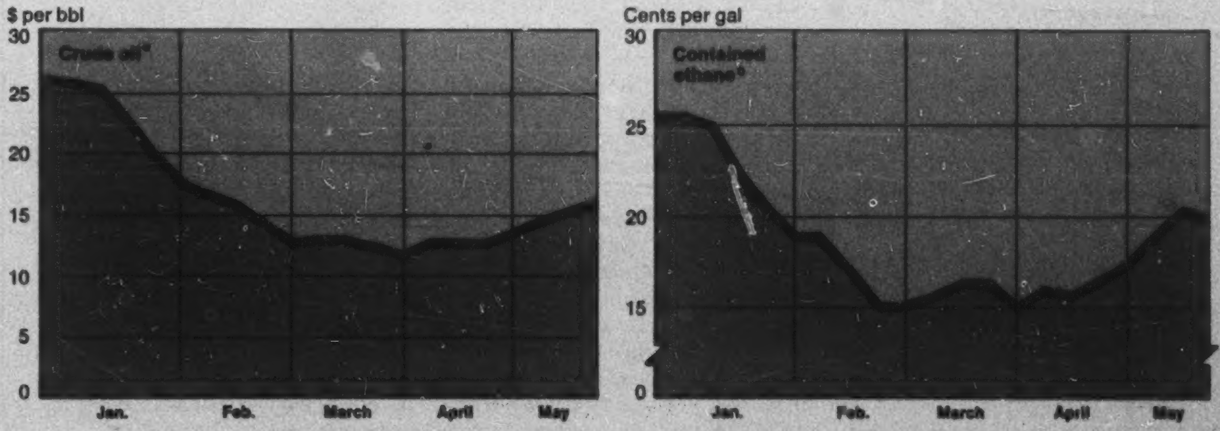
Key Chemicals

That volatility has led to a new kind of pricing situation. For major-volume olefins, such as ethylene, selling prices frequently are settled after the month ends. By determining prices after a month's sales are completed, the variations in feedstock costs during the month can be assessed more fairly for both buyers and sellers, or so goes the thinking. That contrasts sharply with former selling situations in which contracts often covered a year and contained seldom-used price reopening clauses allowing price adjustments to be made quarterly.

Some observers continue to forecast stability for feedstock prices later this year and on into 1987, but that stability remains elusive. A recent sign that steam crackers might shift back toward heavier feedstocks (and possibly higher costs) comes from announcements of plans by large natural gas producers to shut down a major part of their production. These moves are likely to reduce recovery of natural gas liquids, causing prices of those feedstocks to rise. The impact of such changes will not be felt until later in 1986, but olefin prices could rise even more than prices of aromatics had increased by late May. Eventually overall profit margins could shrink even more than they have already.

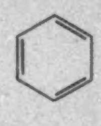
For some details of the near-term outlook for five of the largest basic petrochemicals, please see the following pages.

Prices for feedstocks to make basic petrochemicals begin to rise from recent lows



a Western Texas intermediate. b At Mont Belvieu, in ethane-propane mixtures used as steam cracker feedstocks. Note: Dollars per bbl (42 gal) averaged and rounded to nearest 25 cents; cents per gal averaged and rounded to nearest 0.5 cent. Source: C&EN estimates

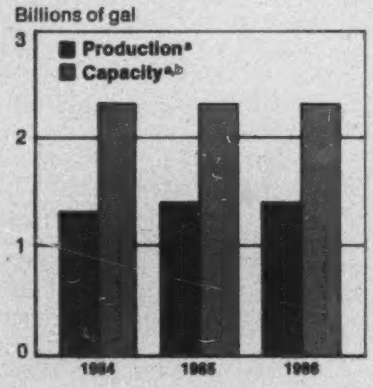
Key Chemicals



Benzene

- ***Production flat***
- ***Capacity holding***
- ***Prices down***

PRODUCTION/CAPACITY



a All grades. b First quarter.

MAJOR PRODUCERS

Amoco Oil, Chevron, Coastal Corp., Exxon Chemical, Shell Oil

HOW MADE

Catalytic reforming and thermal (steam) cracking of petroleum hydrocarbons and coking of coal with subsequent separation; dealkylation of toluene

MAJOR DERIVATIVES

Ethylbenzene 50%, cumene 20%, cyclohexane 15%, aniline 5%

MAJOR END USES

Fabricated plastics and rubber 55%, phenolic resins 20%, nylons 15%

FOREIGN TRADE

Exports—small and declining to about 10 million gal; imports—large, but may fall below 150 million gal

PRICE

80 to 90 cents per gal, Gulf Coast

Following a modest gain during 1985, benzene production will remain in the doldrums this year. Overall demand for benzene in its major chemical uses—styrene, cumene, cyclohexane, and aniline—will change little. U.S. consumption of those benzene derivatives and their derivatives will increase, but export demands will decline. For benzene itself, the net of imports over exports will decline slightly, but will remain nearly 10% of production.

From slightly less than 1.4 billion gal in 1985, benzene output from all sources in 1986 is estimated to grow about 50 million gal to nearly 1.45 billion gal. The major sources of benzene—catalytic reforming and pyrolysis gasoline (a significant coproduct of steam cracking hydrocarbons heavier than butane to make ethylene)—will change little during 1986. Output of pyrolysis gasoline has begun to decline a bit, following a rise during the first quarter of 1986. The reversal comes from a shift to a slightly lighter mix of feedstocks for steam crackers. Benzene produced by hydrodealkylation and disproportionation of toluene also will slip slightly. The minor quantities of benzene recovered from coking of coal, possibly 30 to 35 million gal, will decline again as coking declines because of low demand.

Capacity to produce benzene from all of its sources totals about 2.3 billion gal, a flexible figure, depending on processing conditions, feedstock choices, and kinds of catalysts employed. It could range as much as 200 million gal above or below that total. No significant changes in nameplate capacity are expected this year, because additional ethylene capacity recently put on stream has been designed to run on light hydrocarbons.

With benzene production at 1.4 billion gal and capacity at about 2.3 billion gal, the U.S. average operating rate for all benzene production sources will be 60%, roughly the level of the past two years. For economic reasons, coal tar and hydrodealkylation units will be run at lower levels of capacity.

Thus far in 1986, prices of benzene and other aromatics have declined drastically as a result of the fall in crude oil prices. Because petroleum reformate accounts for about 45% of benzene production, benzene prices correlate closely with gasoline prices. Gasoline prices currently are a bit unstable owing to a number of factors. They include increasing demand for gasoline as the summer driving season begins, fluctuating crude oil prices, and changing travel plans as vacationers seek to avoid foreign travel. Benzene prices, which dropped below 75 cents a gal on a spot basis on the Gulf Coast, are moving toward 90 cents this month. Prices could be higher by July 1, depending on need for reformate and the octane value of the reformate, which would result from catalyst and processing changes. However, imports of benzene will dampen efforts to raise prices.

Prices of benzene have relatively little effect on chemical use, because no substitute exists for benzene in such uses. More than half of chemically used benzene goes to make ethylbenzene for styrene. Although U.S. consumption of styrene is increasing because of growing demand for nondurables or disposables, exports are declining as other sources replace U.S.-produced styrene. Consumption of benzene in styrene, therefore, will be down marginally during 1986.

Among other uses of benzene, cumene production will increase a little. Demand for phenol that goes to various resins and plastics has improved, but an inventory of finished plywood dampens the market. Output of cyclohexane, used mainly for making nylon fibers, will be increasing as a result of lower imports from Canada. However, the increase in cyclohexane production, at less than 15% of benzene demand, will not completely offset the decline in demand for making styrene.

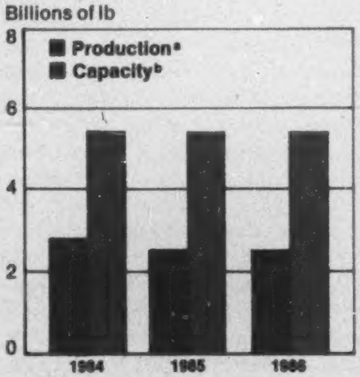
Key Chemicals

$CH_2{=}CH{-}CH{=}CH_2$

Butadiene

- ***Production holding***
- ***Much capacity down***
- ***Prices weakening***

PRODUCTION/CAPACITY



a All grades. b First quarter; extraction capacity; includes shut-down capacity not expected to restart.

MAJOR PRODUCERS

Amoco Chemicals, El Paso Products, Exxon Chemical, Shell Chemical, Texas Petrochemicals

HOW MADE

Thermal (steam) cracking of hydrocarbons ranging from ethane to heavy gas oil; dehydrogenation of butylenes

MAJOR DERIVATIVES

Styrene-butadiene rubber and latex 45%, polybutadiene rubber 20%

MAJOR END USES

Fabricated rubber products 75%, fabricated plastics 10%, fibers 10%

FOREIGN TRADE

Exports—small, declining to 125 million lb; imports—large, but falling to 500 million lb

PRICE

About 15 cents per lb

Butadiene consumption is expected to decline in 1986. Production, however, will hold close to last year's level, because most butadiene is made as a coproduct of ethylene in steam crackers. Despite use of lighter hydrocarbon feedstocks, increased ethylene production will keep butadiene production high. Imports of butadiene are forecast to decline steeply as consumers require less and inventories are drawn down. Prices will continue to be under pressure from imported material and from consumer expectations that lower production costs (resulting from lower crude oil prices) will be passed on to them.

More than 75% of butadiene consumption goes into synthetic rubber. This year, U.S. synthetic rubber production likely will be lower than in 1985. That slump will stem mainly from increased imports of finished rubber products, especially tires on imported cars and replacement market tires.

Earlier this year, butadiene production increased, resulting from a shift to slightly heavier feedstocks for steam crackers whose primary product is ethylene. An annualized production rate based on the first quarter exceeds 2.5 billion lb per year. But, because demand to make the several kinds of synthetic rubber (of which butadiene is an important comonomer) is stable to slightly down, inventories of butadiene increased in the first quarter.

During the current quarter, butadiene production apparently slowed, even with startup of the two additional steam crackers. Those crackers are expected to be fed mostly ethane and propane, which will minimize butadiene output. The production slowdown results from a review by steam cracker operators of the total economics of their plants. Their analysis shows that using heavier feedstocks is now less profitable because selling prices for the coproducts, which include butadiene, have declined. The shift to lighter hydrocarbon feedstocks that began in April has held through May. The economics of producing gasoline for the approaching summer driving season will cause light hydrocarbons to be preferable feedstocks for steam crackers for about two months.

Butadiene inventories dropped during April probably because of the reduced output from steam crackers. Inventories are expected to decline further during this quarter unless unusually large imports of butadiene arrive and are not bought at low spot prices.

As with other basic petrochemicals, prices for butadiene have fallen drastically this year. As 1986 began, list prices were nearly 30 cents per lb. By early May, butadiene prices, which also are similar to those of most other basic petrochemicals, were quite volatile at about 15 cents per lb, with rumors of spot prices for imported butadiene on ships nearing the coast, running 10 to 20% lower.

The low spot prices for butadiene indicate changes that could be coming in imports, which have accounted for more than a quarter of demand at times. The net-back profit received by European sources after deducting production and shipping costs has disappeared. Another cause for declines in imports stems from the shift in feedstock composition for steam crackers in Europe, reducing butadiene production. That results from increased quantities of light hydrocarbons being produced from the North Sea and imported from northern Africa and the Middle East.

Because of diminished profits and production in Europe, imports of butadiene will be reduced as much as a third in 1986. Butadiene imports in 1985 have been estimated to total 830 million lb. In the first quarter of 1986, imports were 114 million lb, down nearly two thirds from the 322 million lb imported in first-quarter 1985. Annualizing the first-quarter 1986 imports gives a yearly total of only 456 million lb, less than most early forecasts of about 500 million lb. The reduced imports, therefore, will account for practically all of the decline in U.S. butadiene consumption.

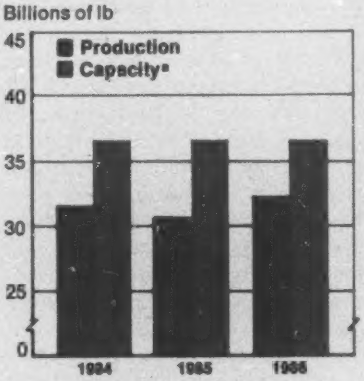
Key Chemicals

$CH_2{=}CH_2$

Ethylene

- ***Production improving***
- ***Capacity unchanged***
- ***Prices down***

PRODUCTION/CAPACITY



a First quarter; includes 2 billion lb of shut-down capacity not expected to restart.

MAJOR PRODUCERS

Amoco Chemicals, Exxon Chemical, Lyondell Petrochemical (Arco), Phillips, Shell Chemical

HOW MADE

Thermal (steam) and catalytic cracking of hydrocarbons ranging from ethane to heavy gas oil

MAJOR DERIVATIVES

Polymers 50%, ethylene oxide 20%, vinyl chloride 15%, styrene 10%

MAJOR END USES

Fabricated plastics 70%, antifreeze 10%, fibers 5%, solvents 5%

FOREIGN TRADE

Exports and imports negligible

PRICE

Volatile, ranging from 14.5 to 15.5 cents per lb

Ethylene production this quarter is expected to exceed the 8.07 billion lb output for the first quarter of 1986. Thus, producers will have their best quarter of the past three years. With output of all major derivatives at near record levels, demand for ethylene remains strong. As crude oil prices move up from recent historical lows, feedstock prices are firming, but ethylene prices have yet to reflect higher production costs.

Later this year, because of inventory building and seasonal declines in consumption, ethylene production could slow slightly from the current pace. Some maintenance shutdowns are anticipated for the second half of 1986, which (along with the usual brief interruptions due to power outages and equipment malfunctions) will push output down some.

Production of ethylene in 1986 will total 32 billion lb, up 5% from a preliminary estimate of 30.5 billion lb last year. The 1986 estimate includes some output from at least two startups of units that either had been shut down for a long period of time or were an addition to existing capacity. This quarter, about 1 billion lb per year of additional ethylene capacity came on stream at plants owned by Occidental Chemical and Phillips. Those units could contribute 500 million lb of production this year. Because of the current high rate of plant operation, an additional 300 million to 500 million lb of capacity may be added during the year through debottlenecking efforts at companies that operate steam crackers.

As 1986 began, operable ethylene nameplate capacity totaled about 34.5 billion lb. Another 2 billion lb of capacity remained on stand-by. If the capacity recently started up contributes 500 million lb of operable capacity during 1986, the operating rate for in-place capacity will be 86.5% of nameplate, one of the highest rates in recent years. The operating rate of actual operable units, however, will be even higher—more than 91%, which is the full rate for effective capacity.

That operating level for steam crackers making ethylene indicates optimum efficiency. Pricing, however, doesn't reflect the full capacity operations. Selling prices for ethylene moved up strongly at the end of last year, but since then they have declined precipitously. At the end of May, most ethylene was selling for about 15 cents per lb, down 4 to 5 cents since January. Buyers who continue to cite declining prices of crude oil and of gas and gas liquids this year are keeping strong pressure on ethylene pricing. Recent increases in crude oil demand and expected increases in gasoline and jet fuel demand this summer likely will offset pressure for lower ethylene prices. Those demand increases could cause ethylene feedstock prices to firm. Whether producers will resist demands to lower prices and try to implement increases beginning July 1 is being debated on the Gulf Coast.

The strong demand for ethylene and ethylene derivatives plus a large drawdown of inventory during the fourth quarter of 1985 could put the industry in a precarious position should an accident occur such as happened at the major storage area at Mont Belvieu, Tex., late last year. During the first quarter of 1986, inventories of ethylene were built from about 900 million lb to nearly 1.2 billion lb. Some inventory drawdown occurred during April and early May as demand for derivatives pressured producers. That pressure now has eased and inventories could be back to about 1.2 billion lb. The higher inventory, however, amounts to only about a two-week supply if annual production totals 32 billion lb.

The 1986 surge in ethylene production, in capacity utilization, and in profitability could spur some producers to consider increasing longer-term supply. However, those factors are not sufficient to prompt a company's board of directors to vote capital for a new steam cracker in the U.S.

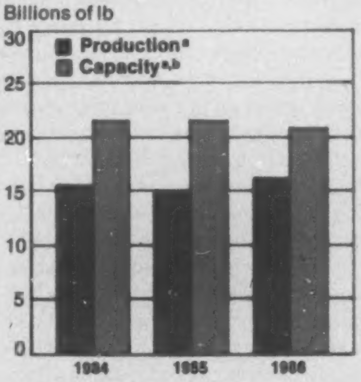
Key Chemicals

$CH_2{=}CH{-}CH_3$

Propylene

- ***Production rising***
- ***Capacity steady***
- ***Prices under pressure***

PRODUCTION/CAPACITY



a All grades. b First quarter; some shut-down capacity not expected to restart.

MAJOR PRODUCERS

Amoco Chemicals, Exxon Chemical, Lyondell Petrochemical (Arco), Phillips, Shell Chemical

HOW MADE

Thermal (steam) and catalytic cracking of hydrocarbons ranging from ethane to heavy gas oil

MAJOR DERIVATIVES

Polymers 35%, acrylonitrile 15%, propylene oxide 10%, cumene 10%,

MAJOR END USES

Fabricated plastics 60%, fibers 15%, solvents 10%

FOREIGN TRADE

Exports—negligible; imports—tiny, about 500 million lb

PRICE

Chemical grade 11 cents per lb, polymer grade 12 cents per lb

Propylene production this year will have the best growth of any of the major-volume basic petrochemicals, with demand spurred mainly by growth in polypropylene. The capacity to make or recover propylene will decline slightly because of shutdowns, but it is sufficient to meet demand.

Propylene produced to make various chemicals and polymers in 1986 could total 16 billion lb, up more than 7% from about 14.9 billion lb in 1985. That estimate is based on the likelihood that the high growth in consumption during the first quarter will be repeated and that the general economy will grow modestly because of lower crude oil prices. Despite a large excess capacity to make propylene, such a level of growth, however, will decline late in 1986 and on into 1987.

Propylene capacity depends on petroleum refining and ethylene manufacture. Potential refinery sources of propylene exceed ethylene manufacture two to one. However, economics radically reduce the amount of refinery-produced propylene that can be recovered. For example, significant quantities of propylene in off-gas streams at refineries are burned because of the high cost of recovering propylene from the low concentrations in the streams. In contrast to refinery propylene, practically all propylene produced as a coproduct of ethylene in steam crackers is recovered and purified. Such coproduction accounts for most of the polymer-grade propylene (99.5%) consumed. Estimates of capacity for propylene are based on the composition of feedstocks to steam crackers and to refinery catalytic crackers, on severity of operation, and on purification capacity for refinery cracking units. At the beginning of 1986, those sources had a practical total of 21 billion lb a year, with a possible variation of ±5%.

Use of capacity varies widely. During the early part of this year, propylene output from steam crackers rose as feedstock was shifted to heavier hydrocarbons. At the same time, gasoline production was held down, reducing refinery cracking operations. The feedstocks to steam crackers now have been lightened, and refiners are pushing gasoline output higher. Refinery propylene production and consumption as an alkylation material have risen. The value of propylene contained in cracked gases streams has risen, but may have topped out temporarily as supplies of other suitable alkylate materials, such as butylenes, have become limited.

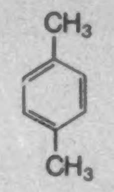
The shifts in production, particularly at refineries, have made propylene pricing volatile. Recent prices are 11 cents per lb for chemical grade (90 to 95%) and 12 cents per lb for polymer grade. Because such a large share of propylene is produced from hydrocarbons heavier than propane, price increases are expected as crude oil prices rise. Ethane and propane prices generally will follow along.

Prices for most propylene derivatives haven't fallen so much, partly because of the high level of operation of polypropylene plants. In 1986, the average operating rate will be above 90%. Polypropylene requires about 35% of the propylene consumed in the U.S. Growth in polypropylene demand is expected to hold at about 5% annually. Capacity could become limited, but not until 1987 or later, depending on debottlenecking and processing improvements.

Acrylonitrile falls a distant second as a chemical consumer of propylene. The major domestic use of acrylonitrile is in fibers, and that use is suffering along with all segments of the textile industry.

Most of the other chemical uses of propylene—cumene, propylene oxide, isopropyl alcohol, oxo alcohols, and other smaller uses—are growing slowly. Although those account for half of chemical- and polymer-grade propylene consumption, they are not expected to have so much effect on demand for propylene as will polypropylene.

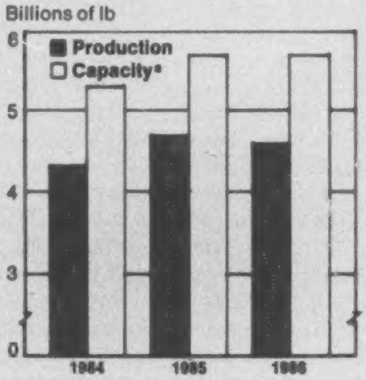
Key Chemicals



p-Xylene

- ***Production may fall***
- ***Capacity flat***
- ***Prices down***

PRODUCTION/CAPACITY



a First quarter.

MAJOR PRODUCERS

Amoco Chemicals, Arco Chemical, Chevron Chemical, Exxon Chemical, Phillips

HOW MADE

Reforming and thermal (steam) cracking of petroleum hydrocarbons and subsequent separation

MAJOR DERIVATIVES

Dimethyl terephthalate 55%, terephthalic acid 45%

MAJOR END USES

Polyester fibers 75%, molded items (mostly bottles) 15%, films 10%

FOREIGN TRADE

Exports—declining to about 1.1 billion lb; imports—holding at about 100 million lb

PRICE

About 19.5 cents per lb, Gulf Coast

Prospects for U.S. production of *p*-xylene in 1986 are good but less favorable than in 1985. Possible shifts in export demand late this year, plus uncertainty in demand for polyester fibers and bottle resins, make it difficult to pin down an estimate for 1986 production. Consumers of *p*-xylene have been asking for and now are getting, or soon will be, higher-purity material, possibly reducing plant capacity.

Because of changes in the various factors that affect *p*-xylene demand, production forecasts now cluster around 4.6 billion lb for 1986, down about 2% from 1985. Increased consumption of polyester bottle resins is certain to push up demand for *p*-xylene. Exports are expected to decline late this year, as new capacity comes on stream in the Far East. In the second half of 1986, pressure from cotton prices and imported garments will work against consumption of polyester fibers.

If production in 1986 totals 4.6 billion lb and capacity remains at 5.7 billion lb, the average plant operating rate will be just under 80%. That obviously low rate doesn't take into account the efforts that producers are making to increase product *p*-xylene purity to 99.5%. Some plants have been shut down for a month at a time so that equipment can be installed and process changes can be made to obtain such purity. Even after changes in a plant have been made, production likely will move up slowly until operating experience develops. As a result, the actual operable capacity to make *p*-xylene may decline 10% during 1986. If that reduction occurs, the operating rate for this year will move to about 90%.

Uncertainties of demand and the move toward higher purity have kept *p*-xylene prices relatively higher than prices of other aromatics during the crude oil price declines. With current demand for gasoline increasing, mixed xylenes, important sources for octane values, could rise in price. Supplies of mixed xylenes, source of *p*-xylene, are tightening as well. Producers of *p*-xylene are expected to pass on these increased costs of raw materials and of processing for higher purity.

The biggest unknown in *p*-xylene output for 1986 lies in export demand. Rumors abound that U.S. exports will be reduced soon by new capacity being built in Japan and in other Far Eastern countries. Any possible reductions in exports to Japan could be offset by increases in exports to Mexico, where operating problems with its *p*-xylene plant are limiting production, and by exports to Indonesia where startup of a terephthalic acid plant is beginning. The net of exports over imports in 1986 could balance out at about 1.1 billion lb, down modestly from the 1985 net.

Except for small quantities consumed in a few tiny uses, all *p*-xylene consumed in the U.S. goes to make dimethyl terephthalate and terephthalic acid in a ratio of roughly 55:45. Those materials, in turn, go to make polyesters—almost entirely ethylene and butylene derivatives. Some of the polyester is exported, but most is fabricated into fibers, films, and molded items, mostly bottles.

In the U.S., the polyester fiber demand for *p*-xylene likely will fall again, because apparel imports and cotton consumption are expected to rise. Cotton consumption will increase as prices decrease this summer and as fashion moves more toward all-cotton fabrics. Such changes could be over by the end of the year, but they will affect *p*-xylene demand throughout 1986.

Polyester bottle resins continue to be the bright spot in *p*-xylene demand. The resins could require 350 million lb of *p*-xylene this year, up at least 10% from consumption in 1985. The growth in the market for bottle resins will continue erratically as technical developments make it possible to use these resins for smaller-sized bottles and hot-fill applications. The market for films, which require relatively small quantities of polyester, is not growing very fast.

Facts & Figures

for the chemical industry

Reflecting the sluggish performance of the overall economy, the U.S. chemical industry in 1985 experienced a year of moderate growth but mixed financial results.

For the industry as a whole, production increased, with plastics and a handful of specialty products setting the pace. On the other hand, in such major areas as inorganic chemicals, man-made fibers, and especially agricultural chemicals, 1985 was a dull if not downright depressed year.

Financially, the record was even more confused. In a widespread effort to revamp the industry's structure and enhance operating efficiency, many companies, both large and small, undertook a dizzying assortment of asset write-downs and spinoffs, staff reduction programs, and various accounting changes. The resulting special charges and credits drastically affected 1985 income statements for the industry as a whole.

Those moves, however, probably will set the stage for a better record in 1986. Output is likely to edge higher again, albeit rather shakily. Profits already are looking stronger. And the weaker U.S. dollar promises relief from one long-standing problem by improving the competitive position of U.S. chemical producers against their counterparts overseas.

The data presented on the following pages of C&EN's annual Facts & Figures issue illustrate these trends statistically, providing a measure of the chemical industry's recent performance in the U.S. and, to a lesser extent, in several other important chemical-producing nations. The data pulled together here come from a diverse variety of sources, such as government agencies, trade associations, and international organizations, as well as the individual companies that comprise the complex industry. The data, in many cases, have been used by C&EN's staff to develop analytical measures and comparisons that help put the industry's recent results into better perspective.

at a glance

Section One: Production

In the U.S. chemical industry, output continued to expand in 1985. But the pace slowed markedly from the year before. And for many sectors of the industry, production actually fell a bit from the 1984 level. Plastics was a strong area. On the other hand, man-made fibers had a mediocre year, as imports cut into U.S. demand. A poor year for U.S. farmers, meanwhile, resulted in a decline in production of agricultural chemicals. Page 34

Section Two: Finance

Earnings declined for U.S. chemical companies in 1985, after three years of growth, as sales stagnated, prices came under pressure, and chemicals produced abroad cut into markets for made-in-America products. Capital spending, meanwhile, continues to expand, although the increase this year is likely to be slim. Budgets for R&D also are showing little or no prospects for increases this year. Page 46

Section Three: Employment

The number of workers employed in the chemical industry declined last year, after rising in 1984, to the lowest level in the past decade. But with output up slightly, the productivity of the industry's work force improved from the year before and unit labor costs were down. Page 61

Section Four: Foreign Trade

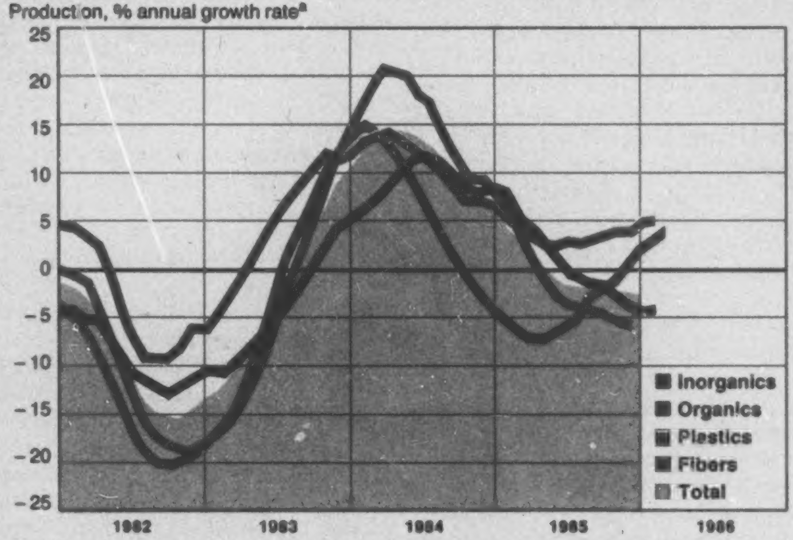
World trade in chemicals has slipped from its peak level of 1984, largely because of lower imports on the part of underdeveloped nations. And the long-standing U.S. trade surplus in chemicals continued to shrink, as imports rose but exports, hurt by a strong U.S. dollar, dwindled. Page 66

Section Five: Foreign Chemical Industries

Outside the U.S., 1985 was a mixture of good and bad for chemical producers. Profitability generally was up for chemical companies in West Europe. However, earnings deteriorated in Japan's petrochemical industry, and the outlook remains poor there. Unsatisfactory prices eroded the profits of chemical companies in Canada. Page 70

1 Production by the U.S. Chemical Industry

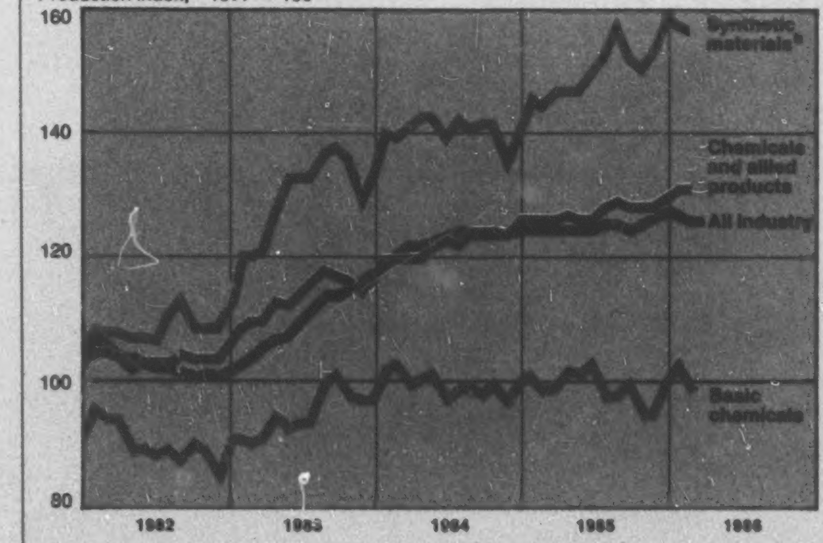
Production up modestly in 1985



Most chemical growth rates decline throughout 1985

Production, % annual growth rate[a]

[a] Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau



Chemical output continues to grow sluggishly

Production index,[a] 1977 = 100

[a] Seasonally adjusted. [b] Includes plastics, synthetic rubber, and man-made fibers. **Source:** Federal Reserve Board

Production by the U.S. chemical industry continued to grow sluggishly throughout 1985, increasing only about 4% over 1984. Yet chemical firms outperformed U.S. manufacturers as a whole, whose output grew only 3% from the year before. However, production of chemical plants in the early months of 1986 leveled off and even dropped in some sectors.

The largest gains in chemical output for 1985 were for plastics and for soap and toiletries. Demand for new housing and autos, spurred by lower interest rates, helped keep demand for plastics growing healthily.

Plastics materials' output was up 10% in 1985—the third new high in as many years. Strong gains were made by major thermoplastics, most notably high-density polyethylene. Thermosetting resins did not perform so well, on the other hand, with output increasing an average of only 1%. After two strong years, synthetic rubber production dropped 11%. Man-made fibers endured another mediocre year, as imported textile products undercut domestic demand, with only production of olefins registering an increase.

Among chemical products, output of soap and toiletries was up 12%. Production of drugs and medicines grew 2% in 1985, however, and production of paints dropped 1%.

Output of basic organic chemicals increased 3% in 1985, but basic inorganic chemicals fared less well. Only production of industrial gases grew in 1985 compared with 1984. Output of alkalies and chlorine, inorganic pigments, and other inorganic chemicals, including acids and fertilizer materials, all dropped off slightly last year. In addition, farmers' financial problems resulted in agricultural chemicals production decreasing 3%.

TOP 50 CHEMICALS:Output steady for organic chemicals but down for inorganics

Rank			Billions of lb		Common units[b]		Average annual growth			
1985	1984[a]		1985	1984	1985	1984	1984–85	1983–84	1980–85	1975–85
1	1	**Sulfuric acid**	79.23	83.60	39,615 tt	41,802 tt	−5.2%	11.6%	−2.1%	2.0%
2	2	**Nitrogen**	46.88	47.90	647 bcf	661 bcf	−2.1	18.0	6.2	9.8
3	3	**Ammonia**	32.40	33.38	16,201 tt	16,692 tt	−2.9	19.6	−3.8	−0.1
4	4	**Lime[c]**	31.60	31.98	15,800 tt	15,992 tt	−1.2	7.8	−3.6	−1.4
5	5	**Oxygen**	31.37	31.87	379 bcf	385 bcf	−1.6	11.3	−2.5	0.7
6	6	**Ethylene**	30.55	31.38	30,550 mp	31,383 mp	−2.7	9.4	1.3	4.1
7	8	**Sodium hydroxide**	21.92	21.83	10,959 tt	10,914 tt	0.4	6.7	−1.2	1.3
8	7	**Phosphoric acid**	20.98	22.74	10,492 tt	11,370 tt	−7.7	16.4	−0.7	3.2
9	9	**Chlorine**	20.93	21.40	10,465 tt	10,699 tt	−2.2	7.4	−1.7	1.3
10	10	**Sodium carbonate[d]**	17.19	17.02	8,597 tt	8,511 tt	1.0	0.5	0.8	7.0
11	12	**Nitric acid**	15.56	15.45	7,778 tt	7,726 tt	0.7	10.9	−3.4	0.3
12	11	**Propylene**	14.93	15.56	14,930 mp	15,559 mp	−4.0	11.5	1.8	5.5
13	14	**Ammonium nitrate[e]**	13.81	14.29	6,906 tt	7,146 tt	−3.4	14.5	−5.4	−0.3
14	15	**Ethylene dichloride**	13.63	10.71	13,632 mp	10,710 mp	27.3	−6.9	4.2	5.5
15	13	**Urea[f]**	13.11	14.87	6,556 tt	7,433 tt	−11.8	23.6	−3.5	6.3
16	16	**Benzene**	9.73	9.71	1,321 mg	1,318 mg	0.2	6.9	−8.0	2.6
17	17	**Carbon dioxide[g]**	8.63	9.13	4,315 tt	4,565 tt	−5.5	16.5	7.5	8.8
18	20	**Ethylbenzene**	8.55	7.56	8,547 mp	7,562 mp	13.0	−4.0	2.3	5.9
19	22	**Vinyl chloride**	7.78	6.09	7,775 mp	6,085 mp	27.8	−11.5	3.8	6.4
20	19	**Styrene**	7.45	7.71	7,454 mp	7,709 mp	−3.3	13.3	1.7	4.8
21	23	**Terephthalic acid[h]**	7.17	5.91	7,165 mp	5,912 mp	21.2	5.1	3.4	4.5
22	18	**Methanol**	5.98	8.19	5,979 mp	8,186 mp	−27.0	2.6	−3.5	1.5
23	25	**Ethylene oxide**	5.83	5.70	5,833 mp	5,699 mp	2.4	3.0	2.2	2.7
24	24	**Formaldehyde[i]**	5.70	5.82	5,699 mp	5,815 mp	−2.0	6.4	0.5	2.3
25	26	**Hydrochloric acid**	5.56	5.46	2,780 tt	2,732 tt	1.8	12.9	−0.8	3.3
26	21	**Xylene**	5.25	6.15	729 mg	854 mg	−14.6	17.6	−4.3	1.3
27	27	**Toluene[j]**	4.99	5.28	688 mg	728 mg	−5.5	−6.7	−7.5	−0.2
28	29	***p*-Xylene**	4.72	4.26	4,724 mp	4,264 mp	10.8	3.6	2.2	6.6
29	28	**Ethylene glycol**	4.68	4.82	4,679 mp	4,823 mp	−3.0	9.0	1.3	2.1
30	30	**Ammonium sulfate**	4.10	4.13	2,049 tt	2,067 tt	−0.9	5.7	−0.8	−0.3
31	31	**Cumene**	3.33	3.75	3,328 mp	3,754 mp	−11.3	12.2	−0.8	5.2
32	35	**Acetic acid**	2.88	2.62	2,875 mp	2,619 mp	9.8	−6.7	−0.7	2.7
33	32	**Potash[k]**	2.86	3.45	1,296 tmt	1,564 tmt	−1.71	9.4	−10.4	−5.4
34	34	**Phenol[l]**	2.78	2.89	2,777 mp	2,889 mp	−3.9	9.6	1.6	4.7
35	33	**Carbon black**	2.57	2.89	2,571 mp	2,893 mp	−11.1	15.9	0.2	−0.7
36	36	**Butadiene[m]**	2.53	2.45	2,525 mp	2,452 mp	3.0	4.2	−2.0	−0.3
37	44	**Sodium sulfate[n]**	2.40	1.74	1,199 tt	872 tt	37.5	2.1	1.0	−0.2
38	38	**Acrylonitrile**	2.35	2.22	2,346 mp	2,219 mp	5.7	3.4	5.1	6.8
39	40	**Vinyl acetate**	2.11	2.02	2,112 mp	2,024 mp	4.3	3.1	1.9	5.1
40	37	**Aluminum sulfate**	2.01	2.26	1,003 tt	1,129 tt	−11.2	2.4	−4.8	−1.3
41	43	**Propylene oxide**	1.88	1.78	1,882 mp	1,779 mp	5.8	−4.5	1.3	2.1
42	42	**Acetone**	1.80	1.86	1,801 mp	1,862 mp	−3.3	0.2	−2.8	0.9
43	41	**Cyclohexane**	1.74	1.99	1,743 mp	1,994 mp	−12.6	20.4	−2.4	0.1
44	49	**Methyl *tert*-butyl ether[o]**	1.69	1.38	1,693 mp	1,376 mp	23.0	64.0	nm	nm
45	45	**Titanium dioxide**	1.63	1.67	814 tt	835 tt	−2.5	10.3	2.6	3.0
46	39	**Calcium chloride[p]**	1.60	2.10	800 tt	1,049 tt	−23.7	22.4	−4.0	−3.7
47	46	**Sodium silicate**	1.47	1.50	736 tt	750 tt	−1.9	3.0	−1.8	0.2
48	48	**Adipic acid**	1.30	1.39	1,298 mp	1,390 mp	−6.6	8.6	−2.5	−0.3
49	50	**Sodium tripolyphosphate**	1.21	1.35	607 tt	675 tt	−10.1	0.9	−3.5	−2.4
50	47	**Isopropyl alcohol**	1.12	1.39	1,118 mp	1,394 mp	−19.8	15.3	−9.4	−3.0
TOTAL ORGANICS			**175.55**	**175.46**			**0.1%**	**6.5%**	**−0.1%**	**4.0%**
TOTAL INORGANICS			**365.92**	**377.16**			**−3.0%**	**11.8%**	**−1.4%**	**1.9%**
GRAND TOTAL			**541.48**	**552.62**			**−2.0%**	**10.1%**	**−0.8%**	**2.5%**

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic; synthetic production ended February 1986. e Original solution. f 100% basis. g Liquid and solid only. h Includes both acid and ester without double counting. i 37% by weight. j All grades. k K_2O basis. l Synthetic only. m Rubber grade. n High and low purity. o Production data for earlier years unavailable. p Solid and liquid. nm = not meaningful.

PRODUCTION: For the chemical industry, plastics are strong in 1985 but inorganics weak

Industrial production indexes, 1977 = 100	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Total index	124.5	121.8	109.2	103.1	111.0	108.6	110.7	106.5	100.0	92.6	84.8	2%	4%
Manufacturing, total	127.1	123.9	110.2	102.2	110.5	108.2	111.5	107.1	100.0	91.9	83.4	3	4
Nondurable manufacturing	125.6	122.5	113.7	105.5	109.7	107.0	108.2	105.5	100.0	93.1	84.5	3	4
Chemicals and products	127.1	121.7	114.0	103.8	112.6	106.4	111.4	106.8	100.0	92.8	82.9	4	4
Chemicals and synthetic materials	118.7	114.3	109.1	95.4	109.4	99.4	113.7	108.2	100.0	90.0	77.0	3	4
Basic chemicals	98.7	99.3	95.0	90.6	104.3	107.2	110.1	110.7	100.0	94.8	88.5	−1	1
Alkalies and chlorine	96.9	99.4	91.5	83.3	96.1	104.1	113.6	101.7	100.0	109.9	105.8	−3	−1
Industrial gases	118.6	114.8	114.0	103.9	115.4	105.0	107.2	98.7	100.0	84.3	73.3	3	5
Inorganic pigments	91.6	93.1	91.5	81.7	99.0	97.6	100.8	103.5	100.0	109.2	105.2	−2	−1
Inorganic chemicals, nec	96.6	97.4	92.9	90.9	104.6	109.4	111.1	115.3	100.0	92.4	86.5	−1	1
Industrial organic chemicals	110.3	107.0	104.0	90.3	105.5	89.1	108.1	104.5	100.0	88.5	72.2	3	4
Synthetic materials	149.1	140.3	129.0	108.0	120.2	110.1	125.8	112.2	100.0	89.2	77.0	6	7
Plastics materials	197.3	179.8	158.7	129.9	136.1	122.1	132.6	115.6	100.0	86.7	70.5	10	11
Synthetic rubber	95.4	107.6	98.3	86.8	91.2	93.0	112.1	99.0	100.0	98.9	86.7	−11	1
Man-made fibers	95.1	94.1	95.4	82.9	104.6	97.3	119.4	110.2	100.0	89.8	80.8	1	2
Chemical products	140.5	132.5	123.2	114.7	116.5	113.7	110.1	106.7	100.0	95.4	87.3	6	5
Drugs and medicines	120.9	119.1	118.8	114.2	112.0	112.9	107.5	105.1	100.0	95.9	87.6	2	3
Soap and toiletries	175.6	156.7	139.9	125.4	129.6	121.5	115.0	106.6	100.0	96.3	88.1	12	7
Paints	101.9	102.6	90.1	83.5	86.7	89.7	95.0	104.7	100.0	94.8	90.5	−1	1
Agricultural chemicals	95.7	98.2	86.9	90.2	109.2	107.3	103.9	97.5	100.0	92.5	90.8	−3	1
Petroleum products	86.8	87.4	84.0	84.2	89.4	94.0	101.7	102.5	100.0	92.8	87.3	−1	0
Rubber and plastics products	146.9	143.2	124.3	110.2	116.4	107.8	114.9	107.5	100.0	84.9	73.3	3	7

nec = not elsewhere classified. Source: Federal Reserve Board

MINERALS: Output of most decreases in 1985

Thousands of tons	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Bromine, sold or used[a]	175[b]	193	185	200	189	189	249	223	217	230	204	−9%	−2%
Calcium chloride, production[c,d]	801[b]	1,036	912	853	917	811	981	1,031	968	897	828	−23	0
Iodine, consumption[e,f]	na	3.8[b]	4.1	3.4	4.4	4.4	4.4	4.0	4.3	3.6	3.1	na	na
Imports[f]	2.5[b]	2.6	3.1	2.3	3.0	3.1	3.1	3.4	3.5	3.2	2.7	−4	−1
Lime, sold or used[g]	15,800[b]	15,922	14,867	14,075	18,890	19,037	20,983	20,484	19,987	20,257	19,159	−1	−2
Lithium, consumption[e,h]	3.5[b]	3.2	2.2	2.0	3.2	3.0	3.2	3.4	4.1	2.8	2.9	9	2
Phosphate rock													
Marketable production	56,035	54,230	46,928	41,241	59,110	59,982	56,891	55,156	52,091	49,231	48,806	3	1
Exports	11,931	12,707	13,239	10,849	11,458	15,737	15,827	14,187	14,584	10,398	12,270	−6	0
Potash (K_2O equivalent)[i]													
Production	1,461[b]	1,724	1,575	1,967	2,377	2,468	2,453	2,484	2,457	2,400	2,501	−15	−5
Imports[j]	5,323[b]	5,319	4,894	4,253	5,287	5,481	5,693	5,189	5,076	4,594	3,797	0	3
Apparent consumption	6,373[b]	6,638	6,231	5,647	6,849	6,999	7,626	6,840	6,605	6,149	5,113	−4	2
Salt, total sold or used[k]	39,700[b]	39,225	34,573	37,894	38,915	40,396	45,820	42,696	43,439	44,218	41,057	1	0
Evaporated[l]	5,955[b]	5,492	5,532	5,305	6,209	6,358	6,248	5,872	5,704	5,634	5,372	8	1
Rock[l]	13,895[b]	13,337	12,446	12,884	11,871	11,806	14,891	14,688	14,958	15,668	14,283	4	0
Salt in brine[l]	19,850[b]	20,397	16,595	19,705	20,835	22,231	24,681	22,336	22,777	22,917	21,401	−3	−1
Sodium carbonate, production[d]	8,500[b]	8.511	8.467	7.819	8.281	8.275	8.253	8.290	8.040	7.560	7.130	0	2
Sulfur, production[m]	12,511[b]	11,742	10,240	10,788	13,388	13,080	13,339	12,318	11,824	11,992	12,610	7	0
Apparent consumption[n]	13,228[b]	13,976	12,112	11,088	14,093	15,056	15,145	13,889	12,850	12,060	11,875	−5	1
Frasch, production	5,512[b]	4,622	3,530	4,641	6,997	7,044	7,007	6,226	6,520	7,016	8,077	19	−4
Recovered elemental, production	5,677[b]	5,747	5,462	4,855	4,695	4,490	4,486	4,478	3,995	3,514	3,326	−1	5
Other, production	1,323[b]	1,372	1,249	1,293	1,695	1,547	1,845	1,615	1,310	1,462	1,208	−4	1

a Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. b Preliminary figure. c 75% $CaCl_2$ equivalent. d Natural and synthetic. e Estimated apparent consumption. f Crude elemental iodine. g Includes Puerto Rican production. h Lithium content basis. i Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. j Includes nitrate of potash. k Total obtained by all recovery methods that was sold or used by domestic producers (figures differ slightly from U.S. production figures); figures for 1973–81 include Puerto Rican production. l Sold or used as such. m Sulfur content basis. n Calculated from shipments plus imports minus exports (sulfur content basis). na = not available. Source: Bureau of Mines

ORGANIC CHEMICALS: Production declines more often than it rises last year

Millions of lb unless otherwise noted	Production											Annual change	
	1985^a	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
Acetic acid, synthetic	2,875	2,619	2,807	2,748	2,705	2,977	3,265	2,776	2,570	2,463	2,197	10%	3%
Acetone	1,801	1,862	1,859	1,694	2,144	2,076	2,653	2,519	2,219	1,869	1,640	−3	1
Acrylonitrile	2,346	2,219	2,146	2,035	1,997	1,830	2,018	1,752	1,646	1,518	1,215	6	7
Aniline	758	786	663	557	634	659	690	606	584	544	407	−4	6
Benzene, mg^{b,c}	1,321	1,318	1,232	1,052	1,308	1,534	1,612	1,435	1,371	1,365	959	0	3
Bisphenol A	802	762	643	480	555	530	576	471	455	449	293	5	11
1,3-Butadiene^d	2,525	2,452	2,353	1,915	2,986	2,799	3,583	3,515	3,259	3,507	2,597	3	0
1-Butanol	728	908	833	730	809	790	766	756	660	625	490	−20	4
Caprolactam	1,083	1,027	977	793	928	905^e	945	919	867	780	713	5	4
Carbon tetrachloride	624	713	573	587	726	710	714	737	809	857	906	−12	−4
Chloroform	385	405	362	299	405	273	356	349	302	292	262	−5	4
Cumene	3,328	3,754	3,345	2,743	3,309	3,459	3,917	3,380	2,644	2,716	2,003	−11	5
Cyclohexane	1,742	1,994	1,656	1,275	1,820	1,964	2,425	2,332	2,265	2,187	1,734	−13	0
Dioctyl phthalate	267	301	300	266	304	353	336	409	400	413	312	−11	−2
Dodecylbenzene^e	na	561	545	509	535	563^f	627	526	526	529	495	na	na
Ethanol, synthetic	647	1,060	1,077	1,023	1,317	1,451	1,408	1,267	1,339	1,496	1,429	−39	−8
Ethanolamines^g	538	504	468	416	429	376	420	362	308	286	258	7	8
Ethylbenzene	8,547	7,562	7,876	6,656	7,813	7,642	8,448	8,385	8,312	5,770	4,822	13	6
Ethyl chloride	182	290	282	339	324	396	582	540	612	669	575	−37	−11
Ethylene	30,550	31,383	28,680	24,501	29,418	28,667	29,904	25,955	25,172	22,475	20,499	−3	4
Ethylene dichloride	13,632	10,710	11,506	7,619	9,974	11,108	11,794	11,001	10,997	8,042	7,977	27	6
Ethylene glycol	4,679	4,823	4,425	4,309	4,143	4,386	4,729	3,904	3,675	3,335	3,809	−3	2
Ethylene oxide	5,833	5,699	5,534	4,987	4,937	5,220	5,665	5,012	4,364	4,184	4,467	2	3
2-Ethylhexanol	513	541	387	325	389	367	318	420	493	450	387	−5	3
Formaldehyde, 37%^{h}	5,699	5,815	5,465	4,817	5,721	5,555	5,971	6,381	6,046	5,449	4,558	−2	2
Isopropyl alcohol	1,118	1,394	1,209	1,380	1,669	1,836	1,900	1,730	1,888	1,936	1,521	−20	−3
Maleic anhydride	372	359	299	260	293	304	323	341	294	264	216	4	6
Methanol, synthetic	5,979	8,186	7,982	7,555	8,577	7,153	7,367	6,443	6,453	6,242	6,242	−27	0
Methyl chloride	410	482	409	366	405	362	463	454	476	378	378	−15	1
Methyl ethyl ketone	537	543	531	468	614	692	716	644	635	631	631	−1	−2
Methyl methacrylate	858	917	844	721	592	564	633	570	478	538	497	−6	6
Methylchloroform	592	675	586	595	611	587	656	661	512	428	425	−12	3
Methylene chloride	581	607	584	532	891	780	931	na	745	na	546	−4	1
Perchloroethylene	493	573	547	585	691	765	773	725	614	669	679	−14	−3
Phenol, synthetic^i	2,777	2,889	2,638	2,023	2,578	2,568	2,981	2,682	2,338	2,121	1,746	−4	5
Phthalic anhydride	836	870	838	684	870	818	1,013	978	926	902	702	−4	2
Propylene^j	14,930	15,559	13,959	12,535	13,482	13,676	14,198	13,014	13,328	10,030	8,709	−4	6
Propylene glycol	538	462	484	400	473	488	610	547	489	517	391	16	3
Styrene, monomer	7,454	7,709	6,802	5,942	6,679	6,856	7,484	7,186	6,867	6,301	4,673	−3	5
Terephthalic acid, dimethyl ester^k	7,165	5,912	5,626	4,843	6,235	6,054	6,159	5,954	5,410	5,051	4,614	21	4
Toluene, mg^{b,l}	688	728	780	714	852	1,010	1,001	1,046	1,008	990	695	−5	0
Vinyl acetate	2,112	2,024	1,963	1,876	1,936	1,922	1,982	1,692	1,586	1,481	1,290	4	5
Vinyl chloride	7,775	6,084	6,875	4,902	6,874	6,466	6,389	6,941	5,986	5,677	4,196	28	6
***o*-Xylene**	697	688	781	802	918	995	1,082	1,013	985	854	703	1	0
***p*-Xylene**	4,724	4,264	4,114	3,391	4,532	4,238	4,650	3,516	3,172	2,911	2,484	11	7

a Preliminary. b Tar distillers and coke-oven operators not included. c Specification grades. d Rubber grade. e Includes straight-chain dodecylbenzene, tridecylbenzene, and other straight-chain alkylbenzenes. f Preliminary figure, final figure not available. g Mono-, di-, and triethanolamines. h By weight. i Does not include data for coke ovens and gas-retort ovens. j All grades. k Includes both acid and dimethyl ester (DMT), without double counting. l High-purity toluene, includes material used in blending motor fuel. mg = millions of gallons. na = not available.
Source: International Trade Commission

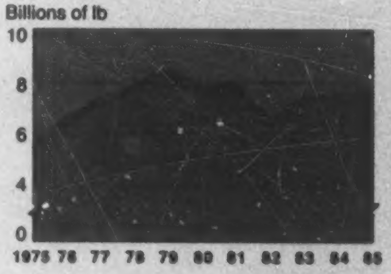
INORGANICS: Output of most chemicals decreases or grows only a little

Thousands of tons unless otherwise noted	Production											Annual change	
	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
Aluminum sulfate[b]	1,003	1,129	1,119	1,154	1,294	1,288	1,315	1,309	1,255	1,202	1,146	−11%	−1%
Ammonia,[c,d] 100%	16,201	16,692	14,072	15,801	19,044	19,653	18,634	17,119	17,765	16,716	16,419	3	0
Ammonium nitrate,[e] 100%	6,906	7,146	6,240	7,091	8,861	9,128	8,293	7,210	7,177	7,186	7,088	3	0
Ammonium sulfate,[d,f] 100%	2,049	2,067	1,956	1,768	2,185	2,136	2,363	2,449	2,264	2,010	2,106	−1	0
Chlorine gas[g]	10,465	10,700	9,960	9,176	10,763	11,421	12,291	11,052	10,573	10,378	9,167	−2	1
Hydrochloric acid,[h] 100%	2,777	2,732	2,468	2,450	2,574	2,888	3,090	2,793	2,668	2,542	2,009	2	3
Hydrogen,[i,j] bcf, 100%	107	109	103	88	105	107	106	90	85	82	74	−2	4
Nitric acid,[k] 100%	7,778	7,726	6,768	7,390	9,093	9,231	8,916	7,934	7,987	7,791	7,527	1	0
Nitrogen gas,[i,j] bcf, 100%	647	661	560	483	490	479	427	379	328	289	252	−2	10
Oxygen, bcf,[i,j] 100%	385	375	346	349	431	431	456	430	392	388	353	3	1
Phosphoric acid, 100% P_2O_5	10,492	11,370	9,767	8,253	9,958	10,848	10,318	9,637	8,745	7,949	7,677	−8	3
Phosphorus[m]	359	386	366	361	426	432	460	441	430	437	450	−7	−2
Sodium chlorate, 100%	259	295	323	291	297	312	269	265	251	199	173	−12	4
Sodium hydroxide, 100%	10,959	10,914	10,039	9,385	10,621	11,625	12,759	11,309	11,000	10,516	9,635	0	1
Sodium phosphate[n]	607	675	669	651	696	727	757	739	717	724	770	−10	−2
Sodium silicate[o]	737	685	710	664	771	805	813	829	760	747	724	8	0
Sodium sulfate,[p] 100%	1,203	901	914	864	1,111	1,140	1,121	1,174	1,199	1,232	1,227	33	0
Sulfuric acid,[q] 100%	39,615	41,802	36,583	33,233	40,742	44,158	43,204	41,314	38,337	34,878	32,360	−5	2
Titanium dioxide,[r] 100%	814	835	760	660	761	727	742	701	687	715	603	−3	3
Urea	6,556	7,433	6,137	6,470	8,062	7,830	7,000	6,273	5,072	4,498	3,799	−12	6

a Preliminary. b Commercial, 17% Al_2O_3; includes municipalities. c Synthetic anhydrous. d Excludes by-product ammonia liquor and ammonium sulfate. e Original solution. f Synthetic and noncoke by-product. g Includes quantities liquefied for use, storage, or shipment. h Includes anhydrous hydrochloric acid production. i High- and low-purity gas. j Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. k Includes unspecified amounts of nitric acid produced but not withdrawn from the system. l Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. m Elemental, white (yellow), and red. n Tripolyphosphate (100% $Na_5P_3O_{10}$). o Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. p Anhydrous, high and low purity, and Glauber's salt. q Gross (new and fortified). r Composite and pure. **Note:** bcf = billions of cubic feet. **Sources:** Department of Commerce, International Trade Commission

MAN-MADE FIBERS: Only olefins show any growth

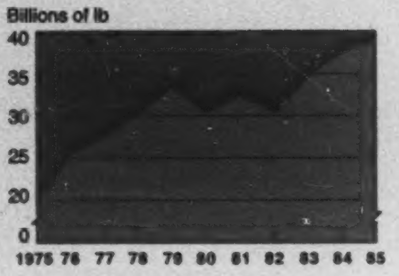
Man-made noncellulosic fibers output



Millions of lb	Production											Annual change	
	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
NONCELLULOSIC FIBERS													
Acrylic[a]	631	671	671	624	691	779	761	726	709	621	525	−6%	2%
Nylon	2343	2412[b]	2419[b]	1927	2332	2358	2,720	2550	2326	2075	1857	−3	2
Olefins[c]	1249	997	906	723	785	748	759	892	635	577	497	25	10
Polyester	3341	3392	3544	3169	4176	3989	4,178	3800	3642	3340	2995	−2	1
CELLULOSIC FIBERS													
Acetate[d]	558	199	229	196	261	316	324	308	290	298	313	na	na
Rayon		421	401	388	509	490	606	597	598	543	436	na	na
GLASS FIBER	na	1394	1168	899	1041	867	1,014	923	787	673	548	na	na
TOTAL	na	9486	9336	7926	9795	9547	10,362	9796	8987	8130	7169	na	na

a Includes modacrylic. b Excludes aramid in 1983 and 1984. c Includes olefin yarn and monofilaments and olefin and vinyon staple and tow. d Includes diacetate and triacetate; excludes production for cigarette filters. na = not available. **Note:** Totals may not add because of rounding. **Source:** Textile Economics Bureau

Plastics production



PLASTICS: Strong growth in thermoplastics leads to new output high

Millions of lb[a]	Production											Annual change	
	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
THERMOSETTING RESINS													
Epoxy[b]	385	406	334	286	336	315	361	299	261	244	198	−5%	7%
Polyester[c]	1,223	1,232	1,084	865	997	947	1,147	1,209	1,067	1,042	834	−1	4
Urea	1,210	1,199	1,172	998	1,165	1,165	1,367	1,122	963	821	690	1	6
Melamine	192	210	180	158	179	167	200	202	200	186	115	−9	5
Phenolic[d]	2,621[e]	2,502[e]	2,477[e]	2,006[e]	2,333[e]	1,499	1,781	1,617	1,458	1,340	1,051	5	nc
TOTAL	5,631	5,549	5,247	4,313	5,010	4,093	4,856	4,449	3,943	3,633	2,888	1%	nc
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	8,889	8,413	8,041	7,503	7,693	7,291	7,793	7,111	6,471	5,813	4,743	6%	6%
High density[g]	6,671	6,085	5,689	4,928	4,695	4,405	5,010	4,201	3,652	3,125	2,468	10	10
Polypropylene	5,139	4,940	4,433	3,477	3,955	3,648	3,841	3,074	2,747	2,632	1,902	4	10
Styrene-acrylonitrile	87	99	93	91	107	111	124	120	115	113	109	−12	−2
Polystyrene	4,054	3,838	3,570	3,191	3,621	3,521	4,005	3,823	3,446	3,195	2,662	6	4
Acrylonitrile-butadiene-styrene and other styrene polymers[h]	2,036	2,127	1,889	1,380	1,745	1,705	2,107	2,012	1,882	1,744	1,227	−4	5
Polyamide, nylon type	399	396	321	228	312	274	327	275	254	247	135	1	11
Polyvinyl chloride and copolymers	6,772	6,760	6,067	5,326	5,707	5,470	6,119	5,723	5,253	4,716	3,646	0	6
Other vinyl resins[i]	190	187	186	177	208	196	220	197	197	225	167	2	0
TOTAL	34,237	32,845	30,289	26,301	28,043	26,621	29,546	26,536	24,017	21,810	17,081	4%	7%

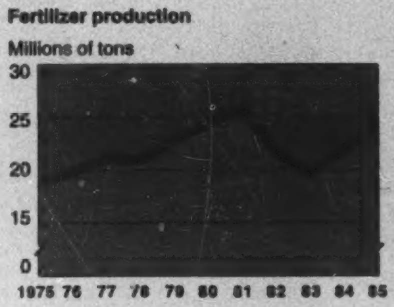
a Dry-weight basis unless otherwise specified. b Unmodified. c Unsaturated. d Includes other tar acid resins. e Gross-weight basis. f Density 0.940 and below. g Density above 0.940. h Includes styrene-butadiene copolymers and other styrene-based polymers. i Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene chloride. nc = not comparable. Note: Totals are for those products listed and exclude some small-volume plastics. Source: Society of the Plastics Industry

SYNTHETIC RUBBER: Total output declines 12% in 1985

Thousands of metric tons	Production											Annual change	
	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
Styrene-butadiene rubber[a]	805	958	904	876	1032	1074	1378	1395	1395	1333	1179	−16%	−4%
Polybutadiene	329	359	333	268	342	311	397	378	361	352	290	−8	1
Nitrile	55	67	55	45	66	63	75	73	70	73	55	−18	0
Ethylene-propylene	215	215	175	123	178	144	175	174	158	130	84	0	10
Other[b]	503	556	468	498	404	423	509	453	432	415	332	−10	4
TOTAL	1907	2155	1935	1830	2022	2015	2534	2473	2416	2303	1940	−12%	0%

a Excludes high-styrene latex. b Includes butyl, polychloroprene, polyisoprene, silicone, and other synthetic elastomers. Some values are estimated. Source: Rubber Manufacturers Association

FERTILIZERS: Nitrogen and phosphate production up strongly in U.S.



Note: Total U.S. production of nitrogen, phosphate, and potash fertilizer. Years ending June 30.
Source: Department of Agriculture

Thousands of tons	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
NITROGEN (N)													
Domestic production	12,532	10,364	9,855	11,598	13,036	12,323	11,106	10,466	10,789	10,572	9343	21%	3%
Imports	3,598	3,940	2,654	2,531	2,455	2,566	2,165	1,866	1,842	1,218	1198	−9	12
Exports	3,227	2,080	2,074	2,499	3,088	2,641	2,468	1,778	1,251	1,239	1115	55	11
Domestic supply	12,903	12,224	10,435	11,630	12,403	12,248	10,803	10,554	11,380	10,551	9426	6	3
PHOSPHATE (P_2O_5)													
Domestic production	10,666	9,611	8,043	7,818	10,471	10,012	9,432	8,245	7,793	7,199	7230	11	4
Imports	141	121	133	193	250	239	236	229	245	221	274	17	−6
Exports	5,547	4,352	3,916	3,751	4,381	3,925	3,848	3,290	2,501	2,175	1860	27	12
Domestic supply	5,260	5,380	4,260	4.260	6.340	6.326	5.820	5.184	5.537	5.245	5644	−2	−1
POTASH (K_2O)													
Domestic production	1,413	1,653	1,859	1,831	2,262	2,474	2,519	2,176	2,584	2,313	2287	−15	−5
Imports	5,355	5,164	4,402	4,797	5,487	5,403	5,085	4,948	4,955	3,910	3847	4	3
Exports	588	528	624	641	876	1,048	999	1,003	994	911	848	11	−4
Domestic supply	6,180	6,289	5,637	5,987	6,873	6,829	6,605	6,121	6,545	5,312	5286	−2	2

Note: Years ending June 30. Source: Department of Agriculture

NITROGEN: Output climbs to highest level in a decade

Thousands of tons (N)	Production 1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	1975–85
Ammonia[a]	5,255	4,179	3587	5,032	5,348	5,270	4,603	4,063	4,307	4,594	3995	26%	3%
Ammonium nitrate[b,c]	836	913	943	1,105	1,157	1,096	1,137	1,044	1,169	1,265	1210	−8	−4
Ammonium sulfate[c]	484	517	395	432	502	521	509	497	547	562	504	−6	0
Urea	1,999	1,786	1692	1,684	1,383	1,572	1,201	1,001	937	941	568	12	13
All other	3,958	2,969	3238	3,345	3,964	3,864	3,656	3,871	3,829	3,210	3066	33	3
TOTAL	**12,532**	**10,364**	**9855**	**11,598**	**12,354**	**12,323**	**11,106**	**10,476**	**10,789**	**10,572**	**9343**	**21%**	**3%**

a Includes aqueous solutions. b Includes ammonium nitrate-limestone mixtures. c Adjusted for estimated quantity going into nonfertilizer uses. Note: Years ending June 30. Source: Department of Agriculture

PHOSPHATE: Production increases for third straight year

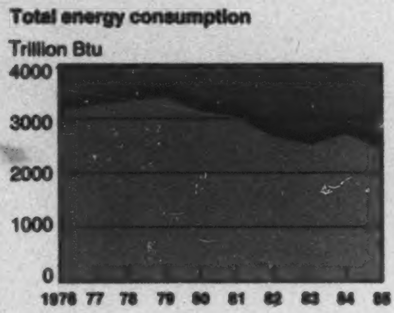
Thousands of tons (P_2O_5)	Production 1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	1975–85
Ammonium phosphate[a]	6,525	6156	5026	4434	6,243	5,519	5082	4548	4118	3380	2572	6%	10%
Concentrated superphosphate	1,145	1172	1184	1151	1,694	1,737	1901	1768	1750	1662	1569	−2	−3
Normal and enriched superphosphate	102	113	110	153	376	384	320	303	376	414	612	−10	−16
All other	2,894	2170	1723	2080	2,613	2,372	2129	1626	1549	1743	2477	33	2
TOTAL	**10,666**	**9611**	**8043**	**7818**	**10,926**	**10,012**	**9432**	**8245**	**7793**	**7199**	**7230**	**11%**	**4%**

a Liquid and solid, excluding that combined with potash salts in the process of manufacture. Note: Years ending June 30. Source: Department of Agriculture

POTASH: **Production continues to dwindle**

Thousands of tons (K_2O)	Production											Annual change	
	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
Potassium chloride	1107	1248	1456	1383	2007	1874	2082	1770	2098	1893	1853	−11%	−5%
Potassium sulfate	271	370	368	413	481	565	402	371	451	385	399	−27	−4
All other	35	35	35	35	35	35	35	35	35	35	35	0	0
TOTAL	1413	1653	1859	1831	2523	2474	2519	2176	2584	2313	2287	−15%	−5%

Note: Years ending June 30. Source: Department of Agriculture



ENERGY USE BY CHEMICAL INDUSTRY: **Total use declines, led by petroleum-based fuels**

Energy source[a]	1985		1984		1983		1982		1972		Change 1972–85	
	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	973	37.8%	1049	37.1%	1010	37.6%	1051	38.7%	1530	47.1%	−557	−36.4%
Purchased electricity[b]	775	30.1	836	29.5	814	30.3	811	29.9	723	22.3	52	7.2
Petroleum-based fuels	441	17.2	543	19.2	458	17.1	472	17.4	566	17.4	−125	−22.1
Light hydrocarbons[c]	320	12.4	332	11.7	308	11.4	325	12.0	310	9.5	10	3.2
Residual fuels	49	1.9	65	2.3	91	3.4	88	3.2	160	4.9	−111	−69.4
Distillate fuels	12	0.5	13	0.5	12	0.4	14	0.5	33	1.0	−21	−63.6
Other fuel[d]	60	2.3	133	4.7	48	1.8	45	1.7	63	1.9	−3	−4.8
Coal and coke	302	11.8	312	11.0	320	11.9	295	10.9	325	10.0	−23	−7.1
Purchased steam	80	3.1	92	3.2	85	3.2	83	3.1	107	3.3	−27	−25.2
TOTAL	2570	100.0%	2831	100.0%	2688	100.1%	2712	100.0%	3251	100.1%	−681	−20.9%

a For energy and process use only, excluding energy equivalent of feedstock. b Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. c Includes propane, liquefied petroleum gas, and other gases. d Includes petroleum coke, gasoline, and other liquids and solids. Note: Data from companies accounting for about 90% of U.S. capacity for basic industrial chemicals. Source: Chemical Manufacturers Association

ENERGY USE BY FERTILIZER INDUSTRY: **Little change during past year**

Energy source[a]	1985		1984		1983		1982		1972		Change[b] 1972–1985	
	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	159.9	79.3%	160.0	78.3%	125.6	77.6%	151.8	76.8%	161.3	79.3%	−1.4	−0.9%
Purchased electricity[c]	38.6	19.1	38.7	18.9	31.9	19.7	33.7	17.1	35.3	17.4	3.3	9.3
Petroleum-based fuels	1.0	0.5	2.8	1.4	0.4	0.3	4.4	2.3	6.2	3.1	−3.5	−83.9
Residual fuels	0.6	0.3	2.2	1.1	0.4	0.2	4.4	2.2	3.8	1.9	−3.2	−84.2
Other fuel[d]	0.4	0.2	0.6	0.3	0.1	0.1	0	0	2.4	1.2	0.4	−83.3
Coal and coke	na	na	na	na	na	na	na	na	0.5	0.2	na	na
Generated steam[e]	2.1	1.1	2.8	1.4	3.9	2.4	7.6	3.8	na	na	na	na
Purchased steam	0	0	0	0	0	0	0	0	0.1	0	−0.1	−100
TOTAL	202	100.0%	204.3	100.0%	161.8	100.0%	197.6	100.0%	203.3	100.0%	−1.3	−0.6%

a For energy and process use only, excluding energy equivalent of feedstock. b Data for 1984 and 1985 cover 21 firms, but one firm is not included in 1972 base owing to unavailability of data because of corporate realignment. c Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. d Includes propane, liquefied petroleum gas, gasoline, diesel oil, kerosine, distillate fuel oil, and other fuels. e Steam generated from fossil fuel, listed prior to 1982 under residual fuels, other fuel, and coal and coke. na = not available. Note: Data from companies accounting for more than 70% of U.S. ammonia capacity. Source: Fertilizer Institute

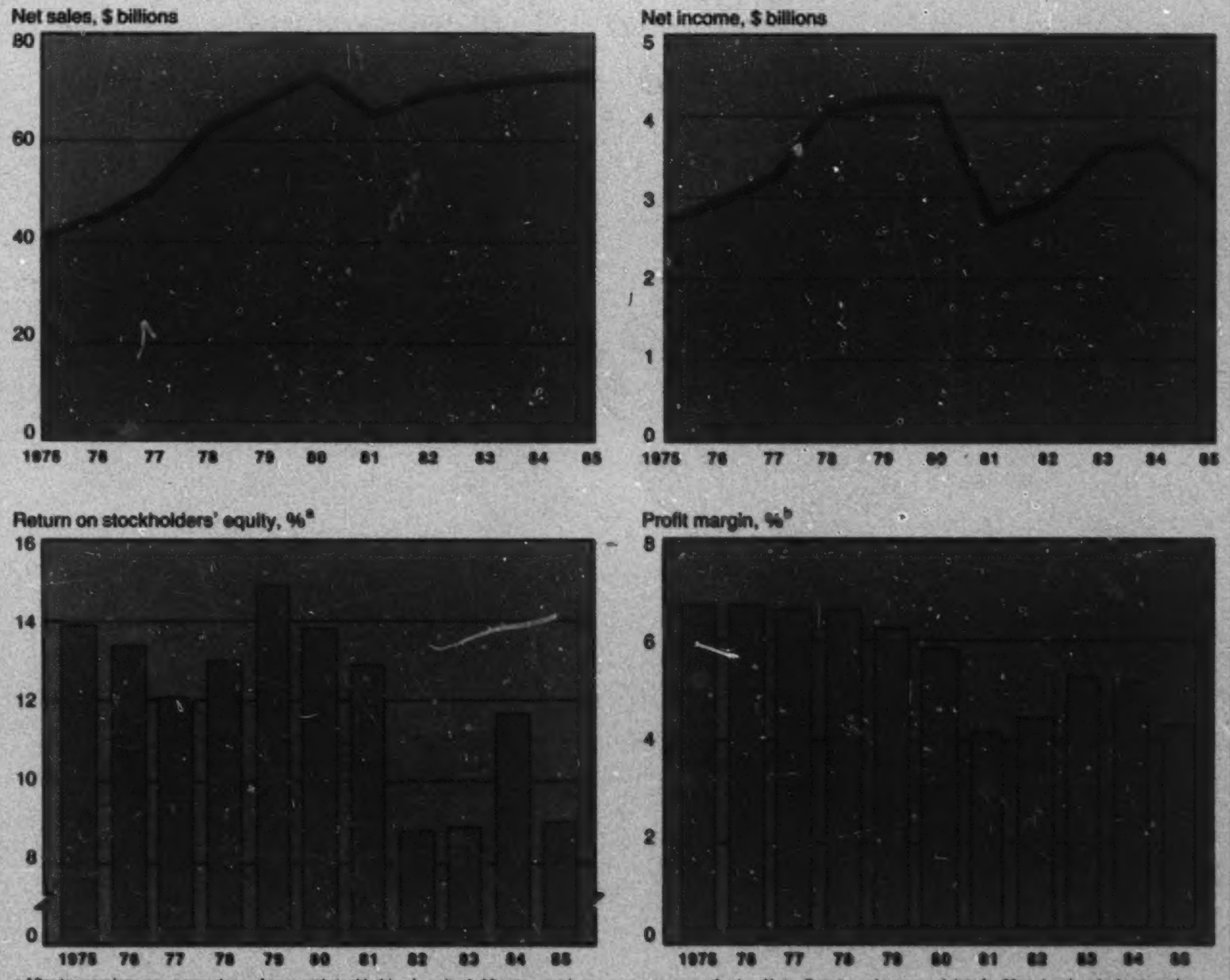
2 Finances of the U.S. Chemical Industry

Earnings, profitability decline in 1985

Sales for the U.S. chemical industry hit a plateau in 1985. And companies in the industry probably wish that earnings and profitability had followed suit. However, both fell from the year before.

The chemical industry was plagued throughout much of the year by a strong dollar, compared with other currencies, that undercut export markets and made foreign products more competitive in the U.S. Imported chemicals not only cut into domestic markets, but in many cases put pressure on prices of U.S. chemicals and stalemated any possibility of increased earnings for U.S. chemical producers. Man-made fibers are a case in point. In addition, some domestic chemical markets, notably agriculture, were weak, resulting in huge drains on earnings for producers of farm chemicals.

As a result, sales for the year were flat, but earnings fell 16% from the year before. In 1985, therefore, chemical profitability lost much of the ground it had gained in the past couple of years. Profit margins last year fell to 3.1% of sales from 3.7% the year before. And return on equity declined to 9.0% from 11.7% in 1984.

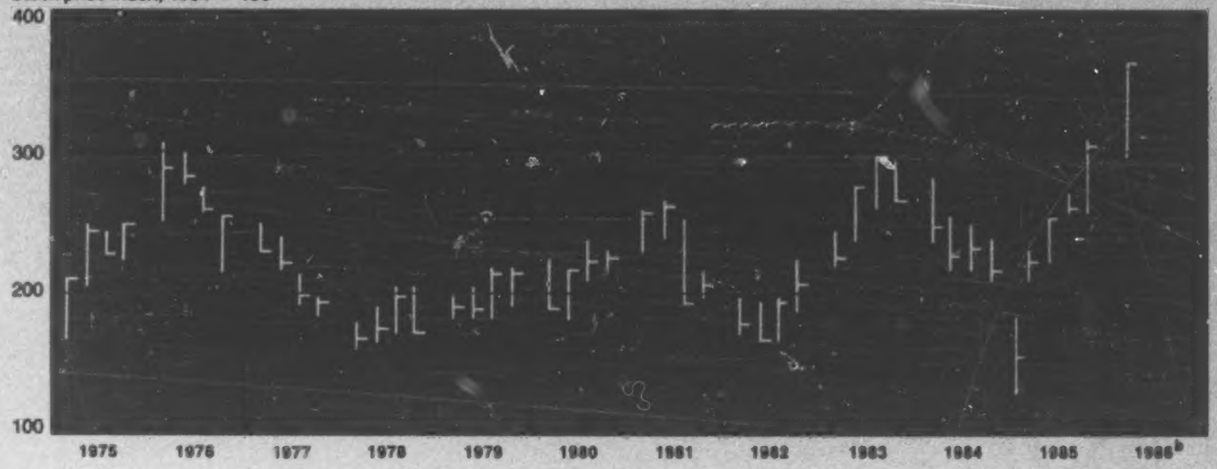


Sales were flat in 1985 for chemical producers, while earnings fell, squeezing profitability

a After-tax earnings as a percentage of year-end stockholders' equity. b After-tax earnings as a percentage of sales. Note: Data based on annual data for 30 major chemical companies.

Chemical stock prices soar during past year

Stock price index, 1954 = 100[a]



[a] C&EN weighted stock price index of American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Hercules, Monsanto, and Union Carbide; weighted according to number of shares outstanding for each company. [b] First quarter.

SHIPMENTS: Growth for chemicals is less than for industry as a whole

$ Billions	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
All manufacturing industries	$2341.2	$2274.9	$2047.4	$1910.1	$1994.6	$1851.0	$1727.2	$1523.4	$1358.4	$1185.6	$1039.1	3%	8%
Chemicals and allied products	214.3	211.8	190.2	172.8	175.1	161.6	147.7	129.8	118.2	104.1	89.7	1	9
Industrial chemicals[b]	71.6	68.7	59.1	55.8	60.7	56.4	52.3	44.8	41.5	35.6	29.4	4	9
Drugs, soap, and toiletries	56.1	53.9	50.4	48.6	44.1	41.9	36.7	34.7	30.6	27.8	24.3	4	9
Petroleum and coal products	194.0	200.6	191.6	206.4	220.3	196.7	148.4	103.9	97.5	82.3	69.5	−3	11
Rubber and plastic products, nec	48.2	52.1	50.3	50.2	46.5	47.3	46.8	43.2	39.6	31.8	27.2	−7	6
Paper and allied products	97.6	95.9	85.1	79.0	79.5	72.6	65.2	57.0	52.1	48.2	41.7	2	9

[a] Preliminary. [b] Excluding pigments. nec = not elsewhere classified. Source: Department of Commerce

PRICES: Small increases and some decreases dominate chemical products

	Annual average											Annual change	
Producer price indexes,[a] 1967 = 100	1985[b]	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
All commodities	308.8	310.3	303.1	299.3	293.4	268.8	235.6	209.3	194.2	183.0	174.9	0%	6%
Industrial commodities	323.9	322.6	315.8	312.3	304.1	274.8	236.5	209.4	195.1	182.4	171.5	0	7
Chemicals and allied products	306.1	300.8	292.9	292.4	287.6	260.3	222.3	198.8	192.8	187.2	181.3	2	5
Industrial chemicals	338.5	341.3	342.9	353.0	363.3	324.0	264.0	225.6	223.9	219.3	206.9	−1	5
Prepared paint	276.8	272.5	264.7	262.9	249.8	235.3	204.4	192.3	182.4	174.4	166.9	2	5
Paint materials	333.8	329.7	305.6	304.6	300.1	273.9	241.2	212.7	205.9	189.8	177.2	1	7
Drugs and pharmaceuticals	256.4	240.0	226.2	210.1	193.5	174.5	159.4	148.1	140.5	134.0	126.6	7	7
Fats and oils, inedible	294.9	371.4	283.7	267.1	295.6	298.0	376.7	315.8	279.0	249.9	255.2	−21	1
Agricultural chemicals and chemical products	281.7	284.8	260.7	292.7	285.0	257.1	214.4	198.4	187.8	188.4	203.6	−1	3
Plastic resins and materials	304.4	308.6	290.2	283.3	289.2	279.2	235.9	199.8	195.7	194.0	180.9	−1	5
Other chemicals and allied products	284.3	277.5	273.7	269.8	254.2	224.5	191.8	181.8	175.7	170.7	168.6	2	5
Rubber and plastics products	245.8	246.8	243.4	241.6	232.6	217.4	194.3	174.8	167.6	159.2	150.2	0	5

[a] Formerly called "wholesale price indexes." [b] Preliminary. Source: Department of Labor

TOP 100 CHEMICAL PRODUCERS: Sales and profits from their chemical operations were lower last

Rank 1985	Rank 1984		Chemical sales 1985 ($ millions)	Change from 1984	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1984	Chemical operating profits as % of total operating profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$11,250	−6.3%	38.2%	Diversified	$870	−21.4%	22.0%	7.7%	$7885	34.3%	11.0%
2	2	**Dow Chemical**	9,508	−0.9	82.4	Basic chemicals	411	−44.5	64.5	4.3	8047	68.0	5.1
3	3	**Exxon**	6,670	−2.9	7.3	Petroleum	385	−43.1	3.5	5.8	5337	7.7	7.2
4	4	**Monsanto**	5,203^{d}	−12.6	77.1	Basic chemicals	477	−28.7	135.9	9.2	4217	47.5	11.3
5	5	**Union Carbide**	3,961	−4.7	44.0	Basic chemicals	413	−14.0	50.0	10.4	4330	44.7	9.5
6	8	**Atlantic Richfield**	3,804	21.0	16.9	Petroleum	73^{e}	−49.3	4.9	1.9	2296	11.3	3.2
7	6	**Shell Oil**	3,318	−1.9	16.3	Petroleum	165	−39.6	5.2	5.0	3891	14.7	4.2
8	7	**Celanese**	3,046	−8.5	100.0	Basic chemicals	127	−53.3	100.0	4.2	2809	100.0	4.5
9	10	**Amoco**	2,905	2.5	10.1	Petroleum	473	35.5	11.5	16.3	2334	9.3	20.3
10	9	**W. R. Grace**	2,868	0.7	39.5	Specialty chemicals	234	−30.8	58.4	8.2	1997	36.8	11.7
11	34	**Chevron**	2,611	137.4	6.0	Petroleum	−163	def	def	def	3010	7.7	def
12	32	**BASF**	2,600^{d}	14.0	100.0	Basic chemicals	na	na	na	na	na	na	na
13	11	**Eastman Kodak**	2,348	−4.7	22.1	Photo equipment	183	−34.9	32.6	7.8	2136	17.6	8.6
14	15	**General Electric**	2,347	10.9	8.0	Electrical products	466	−0.9	13.2	19.9	3876	14.7	12.0
15	13	**Phillips Petroleum**	2,266	−3.6	14.5	Petroleum	219	−0.9	8.0	9.7	1315	9.4	16.7
15	14	**Mobil**	2,266	−3.6	3.7	Petroleum	81	42.1	1.3	3.6	2045	4.9	4.0
17	12	**Allied-Signal**	2,055	−15.5	22.5	Diversified	195	−15.6	21.8	9.5	1979	14.9	9.9
18	16	**Rohm & Haas**	1,966	0.2	95.9	Basic chemicals	270	−18.9	99.3	13.7	1381	98.9	19.6
19	17	**American Cyanamid**	1,830	−3.6	51.8	Basic chemicals	81	−40.2	32.1	4.4	1254	54.6	6.4
20	18	**Hercules**	1,743	−4.4	67.8	Basic chemicals	47	−63.6	35.9	2.7	1409	53.0	3.3
21	19	**Air Products**^{f}	1,674	4.4	91.5	Basic chemicals	312	6.9	114.3	18.6	1937	74.7	16.1
22	37	**Occidental Petroleum**	1,621^{g}	64.6	10.4	Petroleum	100	45.4	5.5	6.2	1721	14.9	5.8
23	24	**Mobay**	1,599	3.0	100.0	Basic chemicals	150	11.2	100.0	9.4	1215	100.0	12.4
24	20	**Ciba-Geigy**	1,540	−1.3	64.2	Specialty chemicals	na	na	na	na	na	na	na
25	26	**Borden**	1,532	5.8	32.5	Dairy products	129	−24.1	32.4	8.4	1336	47.4	9.6
26	23	**Ashland Oil**	1,499	−0.1	18.3	Petroleum	68	23.6	19.3	4.5	496	12.6	13.7
27	27	**B. F. Goodrich**	1,384	−2.8	43.2	Rubber products	79	−30.4	51.1	5.7	1154	51.1	6.9
28	25	**American Hoechst**	1,361^{d}	−7.3	80.4	Basic chemicals	na	na	na	na	na	na	na
29	31	**FMC**	1,261	2.0	38.7	Machinery	143	−23.5	53.2	11.4	1260	46.8	11.4
30	28	**Ethyl**	1,242	−9.0	80.3	Basic chemicals	198	4.2	84.3	16.0	768	49.4	25.8
31	21	**Texaco**	1,220	−20.7	2.6	Petroleum	12	−69.2	0.3	1.0	1010	2.7	1.2
32	28	**U.S. Steel**	1,217	−9.7	6.3	Steel	−1	def	def	def	587	3.2	def
32	30	**Unocal**	1,217	−2.6	10.8	Petroleum	58^{e}	−33.3	17.8	4.8	772	7.2	7.5
34	33	**Olin**	1,147	−2.3	65.5	Basic chemicals	46	−24.5	44.3	4.0	825	51.6	5.6
35	—	**Chesebrough-Pond's**	1,079	nm	40.0	Diversified	60	nm	27.7	5.6	1771	58.9	3.4
36	38	**International Minerals**^{h}	1,057	8.1	61.2	Agrochemicals	135	−7.7	62.8	12.7	1285	65.6	10.5
37	42	**National Distillers**	1,037	−4.0	45.3	Alcoholic beverages	72	−29.6	37.7	6.9	746	36.9	9.6
38	39	**Borg-Warner**	929	−1.6	27.9	Auto equipment	122	0.8	35.8	13.2	437	15.5	28.0
39	40	**CF Industries**	921^{d}	1.4	100.0	Agrochemicals	−1	def	def	def	936	100.0	def
40	42	**Dow Corning**	901	5.4	100.0	Specialty chemicals	95^{e}	4.3	100.0	10.6	na	na	na
41	57	**National Starch**	881	nm	100.0	Specialty chemicals	66	20.0	100.0	7.5	655	100.0	10.1
42	36	**PPG Industries**	841	−15.3	19.4	Glass products	80	−34.0	17.9	9.5	1129	27.6	7.1
43	46	**Reichhold Chemicals**	823	2.6	100.0	Basic chemicals	21	−51.6	100.0	2.6	492	100.0	4.3
44	43	**Lubrizol**	804	−3.4	89.0	Specialty chemicals	93	−8.4	97.5	11.6	603	70.6	15.5
45	44	**Williams Cos.**	742	−10.7	23.6	Agrochemicals	−16	def	def	def	553	12.8	def
46	45	**Diamond Shamrock**	736	−10.3	17.9	Petroleum	121	4.4	33.9	16.5	791	17.1	15.3
47	47	**Farmland Industries**	721	−8.0	24.2	Agricultural supplies	3	−91.5	3.8	0.4	407	31.7	0.7
48	48	**Eli Lilly**	713	−5.8	21.8	Drugs	88	−18.4	10.7	12.4	812	20.5	10.9
48	59	**Cabot**^{i}	712	31.4	50.6	Specialty metals	88	31.8	43.5	12.4	482	30.2	18.3
50	52	**Nalco Chemical**^{j}	682	2.7	100.0	Specialty chemicals	122	5.6	100.0	17.8	542	100.0	22.4

a Operating profit is sales less administrative expenses and cost of sales. b Operating profit from chemicals as a percentage of chemical sales. c Chemical operating profit as a percentage of identifiable chemical assets. d Chemical sales include significant amounts of nonchemical products. e Chemical net profits. f Fiscal year ended Sept. 30. g Does not include all chemical sales. h Fiscal year ends June 30. i Fiscal year ends Nov. 30. j Fiscal year ends Oct. 31. na = not available. nm = not meaningful. def = deficit.

year for more than half of them

Rank 1985	Rank 1984		Chemical sales 1985 ($ millions)	Change from 1984	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1984	Chemical operating profits as % of total operating profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	53	**Pennwalt**	$680	3.8%	67.1%	Basic chemicals	$ 59	13.9%	72.3%	8.7%	$612	63.9%	9.7%
52	41	**Koppers**	619	−30.1	44.2	Diversified	−62	def	def	def	373	35.0	def
53	54	**Morton Thiokol**[h]	616	−5.8	33.8	Diversified	90	10.7	37.6	14.6	543	39.7	16.5
54	58	**Engelhard**	598	6.8	26.4	Specialty metals	62	−6.1	72.9	10.4	528	56.4	11.7
55	70	**Enron**	581	46.8	5.7	Natural gas	34	−26.6	5.5	5.9	590	6.0	5.8
56	72	**Terra Chemicals**	574	55.1	100.0	Agrochemicals	na	na	na	na	na	na	na
56	56	**Witco**	574	−7.9	39.6	Specialty chemicals	57	−12.6	49.5	9.9	265	32.7	21.4
58	63	**NL Industries**	564	19.3	39.6	Petroleum services	127	33.9	105.8	22.5	397	24.9	32.0
59	50	**Standard Oil (Ohio)**	552	−21.9	4.0	Petroleum	27	−38.6	0.9	4.9	549	3.0	4.9
60	74	**SCM**[h]	539[d]	49.4	24.8	Paint	74	99.8	59.5	13.7	483	35.5	15.3
61	—	**Vista Chemicals**[e]	521	nm	100.0	Basic chemicals	na	na	na	na	na	na	na
62	76	**Solvay America**	515	nm	100.0	Basic chemicals	na	na	na	na	na	na	na
63	64	**Polysar**	513	10.6	100.0	Basic chemicals	na	na	na	na	na	na	na
64	62	**International Flavors**	501	5.1	100.0	Specialty chemicals	118	1.5	100.0	23.5	560	100.0	21.0
65	60	**Kerr-McGee**	483	−7.1	14.4	Petroleum	47	def	11.9	9.7	567	15.3	8.3
66	68	**Liquid Air**	459	7.8	84.6	Basic chemicals	58	10.7	94.0	12.6	na	na	na
67	65	**H. B. Fuller**[i]	457	2.4	100.0	Specialty chemicals	31	−4.5	100.0	6.7	246	100.0	12.5
68	61	**Freeport-McMoRan**	451	−8.5	62.5	Agrochemicals	105	−4.5	70.3	23.3	215	10.5	48.8
69	55	**Merck**	450	−29.8	12.7	Drugs	58	−25.4	6.8	13.0	369	7.5	15.8
70	79	**Big Three Industries**	411	21.1	49.3	Petroleum services	104	38.3	75.8	25.4	594	55.6	17.6
71	81	**American Petrofina**	405	27.3	16.8	Petroleum	12	−42.1	def	2.9	314	17.9	3.7
72	69	**Sun Co.**	402	−4.8	2.8	Petroleum	na	na	na	na	na	na	na
73	72	**Rhône-Poulenc**	400	8.1	100.0	Specialty chemicals	na	na	na	na	na	na	na
74	71	**Pfizer**	392	6.6	9.7	Drugs	17	260.0	1.8	4.4	400	9.0	4.3
75	78	**Tyler**	375	8.4	41.1	Diversified chemicals	30	−61.5	0.1	7.9	174	36.7	17.0
76	75	**GAF**	364	2.0	49.8	Specialty chemicals	93	17.2	81.4	25.4	217	24.7	42.6
77	81	**Chemed**	336	5.9	90.3	Specialty chemicals	43	3.8	88.6	12.8	159	69.3	27.1
78	77	**Mississippi Chemical**	325	−6.8	100.0	Farm cooperative	3	−32.3	100.0	0.9	320	100.0	0.9
79	83	**Betz Laboratories**	319	5.1	100.0	Specialty chemicals	61	0.3	100.0	19.0	254	100.0	23.9
80	84	**Vulcan Materials**	292	−3.2	30.1	Nonmetallic minerals	24	−48.4	18.8	8.3	na	na	na
81	85	**Petrolite**[j]	290	2.1	93.9	Specialty chemicals	36	−11.0	106.1	12.4	170	74.4	21.2
82	—	**Dexter**	281	−2.1	44.4	Specialty materials	28	−8.7	42.2	10.0	150	30.9	18.9
83	86	**Great Lakes Chemical**	277	−0.5	100.0	Specialty chemicals	45	−19.8	100.0	16.4	na	na	na
84	—	**Union Camp**	275	−7.0	14.7	Wood products	9	−56.4	7.2	3.2	207	7.8	4.3
84	87	**Aluminum Co. of America**	271	−0.7	5.3	Nonferrous metals	na	na	na	na	na	na	na
86	87	**Ferro**	267[d]	−1.9	41.1	Specialty materials	14	−14.4	37.0	5.1	143	36.4	9.6
87	90	**Emhart**	257	−1.6	14.5	Machinery	19	−17.4	10.6	7.4	132	8.6	14.4
88	91	**Kaiser Aluminum**	255	2.3	12.6	Nonferrous metals	8	−80.0	def	3.1	275	8.4	2.8
89	93	**Stepan**	236	0.4	100.0	Specialty chemicals	9	51.3	100.0	3.9	139	100.0	6.6
90	92	**Loctite**	231	−4.2	100.0	Specialty chemicals	35	−19.0	100.0	15.1	219	100.0	15.9
91	—	**Lonza**	197	9.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
92	66	**Georgia-Pacific**	173	−61.2	3.9	Wood products	na	na	na	na	na	na	na
93	95	**Essex Chemical**	172	−2.2	90.6	Basic chemicals	32	18.5	118.5	18.6	94	66.7	33.9
94	—	**Millmaster Onyx**	170	0.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
95	99	**Sigma-Aldrich**	165	19.4	76.7	Specialty chemicals	47	21.0	89.3	28.6	157	84.1	30.1
96	96	**Agway**	162	−2.7	4.0	Farm cooperative	na	na	na	na	na	na	na
97	97	**First Mississippi**	151	−8.6	55.2	Agrochemicals	31	11.0	81.4	20.6	68	17.3	45.4
98	—	**UGI**	117	3.5	19.4	Natural gas	0	−90.0	def	0.1	133	21.4	0.1
99	100	**Crompton & Knowles**	113	−2.1	48.7	Specialty chemicals	12	−8.2	58.6	11.0	73	55.8	17.2
100	—	**Lawter Chemicals**	97	−1.7	100.0	Specialty chemicals	13	−38.1	100.0	13.7	84	100.0	15.7

FINANCIAL ANALYSIS: Many analytical measures weaken in 1985

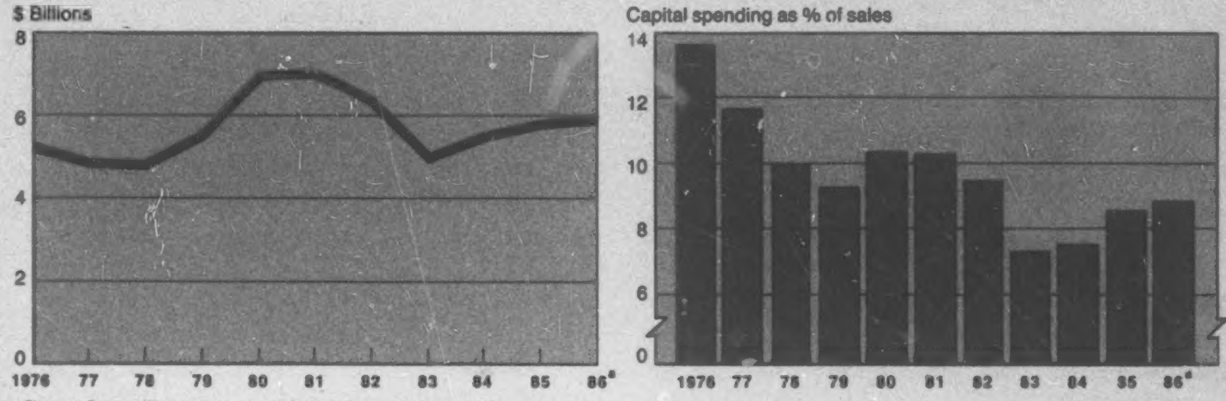
		Profit margin[a]	Return on investment[b]	Debt as % debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									as % of sales	as % of net plant			
SALES OVER $1 BILLION													
Air Products[g]	1985	7.8%	3.8%	30.9%	17.3%	18.8%	$ 98	26.6%	21.4%	22.0%	2.8%	70.5%	56.1%
	1984	8.1	4.2	25.3	17.4	16.3	98	23.0	15.1	16.5	2.5	74.5	56.9
American Cyanamid	1985	3.4	2.7	25.8	29.6	21.9	97	76.0	5.7	18.0	7.1	103.9	44.3
	1984	5.6	4.8	24.0	30.3	21.7	101	42.2	5.2	16.1	6.1	115.9	45.9
Celanese	1985	5.8	3.8	29.9	20.7	18.0	165	34.3	5.2	13.1	3.4	108.4	34.3
	1984	4.8	3.2	36.2	21.0	18.4	155	41.6	8.3	19.0	3.0	116.0	39.9
Dow Chemical	1985	0.5	0.4	40.0	54.8	46.6	217	587.9	7.0	15.7	4.7	97.5	43.2
	1984	4.8	3.6	35.2	53.6	45.9	229	63.2	6.8	15.1	4.4	100.0	46.0
Ethyl	1985	7.6	7.5	33.6	28.3	9.2	147	31.7	5.8	16.1	3.0	99.4	50.6
	1984	7.9	8.4	36.4	24.5	10.5	152	25.0	6.2	18.0	2.4	113.1	51.4
B. F. Goodrich	1985	0.3	0.3	41.7	15.4	15.1	122	374.5	6.3	19.4	2.0	141.6	55.1
	1984	1.8	1.8	34.9	15.4	12.8	116	62.5	4.6	11.7	1.8	129.6	55.6
W. R. Grace	1985	2.5	1.9	38.8	25.4	16.4	58	111.7	6.7	13.4	1.8	95.8	57.1
	1984	2.9	3.0	40.7	18.9	14.0	84	69.8	5.6	14.1	1.2	126.3	59.3
Hercules	1985	5.1	4.4	26.5	25.0	14.9	102	64.9	9.1	23.4	2.9	97.3	50.1
	1984	7.7	6.8	23.5	26.3	13.2	98	40.1	8.5	24.1	2.8	107.6	46.8
International Minerals[h]	1985	7.3	4.4	23.9	17.3	8.3	187	59.5	7.1	10.3	na	83.1	52.3
	1984	7.3	4.2	27.2	20.5	8.8	170	62.3	6.8	9.2	na	78.0	55.5
Monsanto	1985	2.7	1.8	38.0	28.5	18.8	120	102.7	9.6	21.3	8.1	76.0	44.4
	1984	6.6	4.6	18.5	26.6	20.6	132	41.5	9.2	18.2	6.7	105.0	48.8
Morton Thiokol	1985	6.5	8.6	17.8	13.3	13.1	102	25.7	6.4	20.9	1.8	133.9	70.2
	1984	5.5	8.3	19.0	14.1	12.7	108	26.3	4.5	17.2	1.5	154.1	69.6
National Distillers	1985	3.4	3.3	23.2	na	na	na	96.9	3.3	8.5	na	113.3	60.0
	1984	3.1	3.4	25.3	na	na	na	108.2	5.2	15.5	na	118.8	58.1
Olin	1985	2.3	1.6	34.0	7.2	10.3	118	86.9	8.8	21.5	3.0	109.6	39.3
	1984	4.3	3.1	29.9	7.5	8.4	116	35.9	8.0	19.2	2.6	113.3	41.9
PPG Industries	1985	7.0	5.5	35.4	21.5	23.7	116	36.4	10.4	18.2	4.0	106.4	59.3
	1984	7.1	5.9	17.8	22.3	21.4	113	32.4	7.4	13.9	3.5	111.7	59.2
Pennwalt	1985	1.1	0.9	30.1	19.8	18.3	102	319.6	8.9	20.7	3.9	105.7	53.3
	1984	4.3	3.8	19.0	18.0	11.9	107	67.4	8.3	22.1	3.5	117.9	51.5
Rohm & Haas	1985	6.9	5.8	20.7	32.5	26.6	173	34.8	7.8	27.4	6.0	118.3	38.7
	1984	8.4	7.6	15.1	32.6	26.0	172	26.8	6.6	24.2	5.4	125.0	38.4
Union Carbide	1985	2.3	1.4	30.3	29.2	28.9	96	113.4	7.2	11.2	3.1	85.1	54.2
	1984	3.6	2.4	32.4	28.8	29.0	97	70.4	7.0	10.5	2.8	90.4	57.3
Williams Cos.	1985	1.0	0.7	60.3	na	na	191	152.2	12.0	13.5	na	72.4	72.5
	1984	4.3	2.6	59.3	na	na	183	29.6	7.7	8.1	na	74.7	76.5
Witco	1985	3.9	4.3	24.7	14.0	13.5	na	38.4	4.9	19.7	na	178.8	39.3
	1984	4.2	6.1	27.7	13.6	12.1	na	32.7	4.4	18.8	na	197.9	53.0
MEDIAN 1985		**3.4%**	**3.3%**	**30.3%**	**21.5%**	**18.0%**	**$118**	**76.0%**	**7.1%**	**18.2%**	**3.1%**	**103.9%**	**52.3%**
MEDIAN 1984		**4.8%**	**4.2%**	**27.2%**	**21.0%**	**14.0%**	**$113**	**41.5%**	**6.8%**	**16.5%**	**2.8%**	**113.3%**	**53.0%**

a Net income as a percentage of sales. b Net income as a percentage of current assets plus gross plant. c Consolidated sales only. d Foreign identifiable assets as a percentage of total assets. e Thousands of dollars. f Actual spending on construction of new facilities and purchase of new equipment and land in consolidated businesses. g For fiscal year ended Sept. 30. h For fiscal

									CAPITAL SPENDING[f]				
		Profit margin[a]	Return on investment[b]	Debt as % debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	as % of sales	as % of net plant	R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
SALES LESS THAN $1 BILLION													
Betz Laboratories	1985	11.5%	13.3%	0.0%	13.6%	15.1%	$126	55.2%	8.5%	22.0%	3.8%	125.9%	64.8%
	1984	12.1	15.4	0.2	13.5	13.5	124	49.3	8.3	23.2	3.6	137.7	67.2
Chemed	1985	6.6	12.6	36.8	11.4	10.7	62	61.2	2.4	18.8	1.1	144.8	60.0
	1984	5.8	13.0	47.3	10.5	9.9	67	64.7	2.7	22.7	0.8	165.5	62.5
Crompton & Knowles	1985	3.3	5.1	20.6	17.2	21.9	na	57.9	1.5	11.2	2.0	178.0	50.1
	1984	3.4	5.7	21.0	18.9	19.9	100	53.2	1.7	12.7	1.9	186.0	53.7
Essex Chemical	1985	4.5	5.1	45.0	na	na	204	37.6	4.6	13.7	2.2	134.4	60.5
	1984	5.2	5.6	51.8	na	na	207	31.9	3.9	10.9	2.0	129.3	62.1
First Mississippi[h]	1985	6.7	3.7	32.5	12.6	na	374	26.9	23.2	27.0	na	69.1	57.3
	1984	5.9	3.5	31.8	6.4	na	335	31.0	15.2	19.6	na	70.9	59.9
Freeport-McMoRan	1985	15.4	4.1	41.6	na	na	160	22.6	28.7	12.8	na	35.1	66.9
	1984	11.2	3.7	42.7	na	na	175	45.3	22.6	12.1	na	44.2	66.8
H. B. Fuller[i]	1985	2.9	4.6	28.0	38.1	51.1	104	21.8	3.1	14.8	2.1	180.6	63.9
	1984	2.9	5.0	34.0	37.7	49.8	104	20.8	2.9	14.6	2.1	189.4	65.9
GAF Corp.	1985	7.4	7.4	45.5	12.2	6.0	170	7.6	6.4	24.3	1.4	83.3	63.0
	1984	5.6	7.7	25.3	11.1	10.5	192	10.7	2.4	10.0	1.2	161.7	64.2
Great Lakes	1985	10.4	7.6	15.9	19.5	na	na	24.0	7.7	15.5	3.4	85.7	57.2
	1984	12.6	10.8	16.8	18.0	na	167	0.9	10.2	22.0	3.5	99.6	61.0
International Flavors	1985	13.9	10.4	0.0	62.2	46.2	135	59.8	4.4	13.9	6.8	89.5	56.2
	1984	14.5	12.8	0.0	62.3	46.7	129	57.8	4.4	14.9	6.8	105.4	57.9
Lawter International	1985	def	def	9.2	34.1	33.7	na	def	3.3	14.1	2.2	115.2	53.4
	1984	15.1	16.0	7.6	31.5	29.1	na	64.4	3.4	15.6	1.8	126.3	56.1
Liquid Air	1985	5.8	3.7	35.1	34.9	33.6	123	67.5	19.1	24.8	1.8	85.7	58.8
	1984	5.4	3.5	39.9	33.9	36.9	na	76.4	12.5	16.9	1.9	85.8	58.7
Loctite[h]	1985	8.8	8.7	10.4	42.6	48.4	94	34.8	4.9	22.7	3.8	105.7	60.3
	1984	10.9	11.6	10.7	39.0	45.1	98	20.5	2.6	13.6	3.1	106.3	62.2
Lubrizol	1985	6.7	5.7	12.4	47.7	29.5	174	78.1	4.4	13.6	4.8	105.7	48.3
	1984	8.1	7.6	6.0	52.0	31.6	198	64.7	3.5	11.7	3.9	118.5	48.5
Nalco Chemical	1985	10.7	10.7	5.8	21.7	21.3	135	64.1	8.8	24.2	4.7	126.0	49.7
	1984	11.0	11.6	5.1	21.5	20.9	140	64.4	7.9	25.6	4.8	138.6	48.1
Petrolite[j]	1985	7.2	7.0	3.6	22.0	20.0	na	58.5	7.6	28.4	4.1	135.5	45.9
	1984	8.8	8.3	4.6	18.9	14.9	na	47.3	3.8	15.7	3.8	132.8	43.8
Reichhold Chemicals	1985	def	def	36.9	24.3	32.6	180	def	11.9	48.0	2.7	165.8	66.4
	1984	3.2	5.4	18.8	10.3	11.0	191	23.7	3.0	14.1	2.3	214.4	57.5
Sigma-Aldrich	1985	13.5	13.8	10.2	12.2	12.7	86	18.7	8.1	30.1	na	115.1	67.6
	1984	13.5	12.6	9.3	11.6	8.4	82	18.6	6.6	25.9	na	103.1	66.1
Stepan	1985	2.3	2.6	62.5	na	na	264	36.4	8.1	23.2	3.5	169.3	51.6
	1984	2.3	2.7	41.6	na	na	270	38.9	4.9	15.8	3.4	175.4	51.2
MEDIAN 1985		6.7%	5.7%	20.6%	21.9%	25.7%	$135	36.4%	7.6%	22.0%	3.1%	115.2%	58.8%
MEDIAN 1984		8.1%	7.7%	18.8%	18.9%	20.4%	$153	45.3%	3.9%	15.6%	2.7%	129.3%	59.9%

year ended June 30. i For fiscal year ended Nov. 30. j For fiscal year ended Oct. 31. **Note:** Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible. na = not available. def = deficit.

Chemical capital spending is continuing its recovery and increasing relative to sales



a Planned. **Source:** Worldwide data for 13 major U.S. chemical companies

INDUSTRY CAPITAL SPENDING: Budgeted spending falls slightly for chemical industry

$ Billions	1986ᵃ	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Chemicals	$ 17.36	$ 16.45	$ 15.32	$ 12.96	$ 12.66	$ 13.11	$ 11.63	$ 9.81	$ 7.76	$ 7.35	$ 7.37
Iron and steel	4.02	4.10	3.54	3.25	3.78	3.48	3.44	3.21	2.60	2.88	3.13
Nonferrous metals	1.91	1.88	2.13	1.74	1.90	2.51	2.13	1.65	1.46	1.30	1.42
Paper	8.85	8.53	7.21	5.92	5.60	6.11	6.52	5.24	3.80	3.48	2.99
Petroleum	24.53	26.68	25.53	23.14	26.39	25.98	19.57	15.24	13.16	11.82	10.02
Rubber	3.95	3.83	3.11	2.46	2.16	2.15	2.03	2.46	2.33	1.77	1.37
Stone, clay, glass	3.25	3.40	3.09	2.77	2.90	3.41	3.98	3.99	3.15	2.30	1.91
All manufacturing	151.84	153.15	138.82	116.20	120.68	126.54	112.33	95.92	75.58	67.48	58.53

a Estimate. **Source:** Commerce Department

Chemical industry's backlog of unspent funds continues to grow

$ Billions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals	$ 8.0	$ 7.8	$ 7.5	$ 7.4	$ 9.4	$ 9.8	$ 8.5	$ 7.2	$ 7.4	$77.1	$ 6.9
Iron and steel	1.1	2.1	2.2	2.7	5.4	3.9	4.5	4.0	3.6	4.7	5.4
Nonferrous metals	2.3	2.5	3.2	3.2	3.7	3.7	2.9	2.7	2.9	2.4	2.2
Paper	4.3	5.9	4.0	5.1	5.1	4.0	4.2	3.2	2.6	2.0	2.7
Petroleum	26.2	24.7	22.3	22.9	29.7	26.7	16.1	14.6	15.0	12.2	14.1
Rubber	3.1	1.6	1.1	1.0	0.9	1.0	0.9	0.9	0.8	0.7	0.6
Stone, clay, glass	2.0	2.2	1.5	1.6	1.9	2.0	2.3	2.4	2.0	1.5	1.4
All manufacturing	95.0	94.4	73.7	70.8	92.7	91.9	76.7	63.4	56.5	47.5	46.4

Note: Figures are for fourth quarter of each year. **Source:** Conference Board

Chemical companies' spending overseas will hit a new high this year

$ Billionsᵃ	1986ᵇ	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Chemicals & allied products	$ 3.2	$ 2.6	$ 2.6	$ 2.3	$ 2.8	$ 3.0	$ 3.0	$ 2.6	$ 1.9	$ 2.0	$ 2.7
Metals, primary & fabricated	0.7	0.9	1.0	0.9	0.9	0.8	0.9	0.6	0.6	0.5	0.7
Petroleum	15.7	14.9	14.1	15.5	19.7	15.6	14.8	11.0	9.5	8.9	7.9
All manufacturing	17.3	15.3	14.0	13.7	16.8	19.2	19.5	15.4	12.0	10.5	10.9

a By majority-owned foreign affiliates of U.S. companies. b Planned. **Source:** Commerce Department

Capital spending in the U.S. chemical industry continued its upward trend in 1985 and will keep rising in 1986. But it is still far below what it was in the early years of this decade.

C&EN's survey of 13 major chemical companies shows that their total capital spending rose 7% in 1985 to $5.81 billion. The increase will be smaller this year—about 3%. Nevertheless, capital spending will top $6 billion for the first time since 1982. Capital spending will climb to about 8.8% of sales in 1986, moreover compared with 8.5% in 1985 and 7.5% in 1984.

The Commerce Department's latest capital spending survey, meanwhile, shows outlays for new plant and equipment in the broader chemicals and allied products industry was up 7% in 1985 to about $16.7 billion. And the government data show expenditures in 1986 climbing 5.5% to about $17.4 billion. This is a major revision from a Commerce Department survey late last year that indicated chemical capital spending would decline almost 1% in 1986.

Although the chemical industry lagged all manufacturing in the government's survey in 1985, it will be pulling ahead in 1986 in terms of growth. The Commerce Department says that capital spending for all manufacturing last year rose 10% to about $153.2 billion, but in 1986, capital spending will fall about 1% to $151.8 billion.

That's a big downward revision and is caused largely by massive changes for capital spending in the petroleum industry. The Commerce Department changed its outlook for petroleum expenditures in 1986 from an increase of 3% to a decline of 8% as the industry is hard-hit by declining oil prices and increasing availability of crude oil worldwide.

A large backlog of unspent capital appropriations also foretokens an increase in spending for 1986. The Conference Board's survey of capital appropriations shows backlogs for the chemicals and allied products industry at the end of 1985 at $8.0 billion up 3% from the end of 1984. The growth in the backlog in 1985 was much larger for chemicals and allied products than for all manufacturing, for which the backlog in 1985 totaled $95.0 billion, up less than 1% from the end of 1984. This is the reverse of the situation at the end of 1984 when the backlog for chemicals was up only 4% from a year earlier but that for all manufacturing climbed 28%.

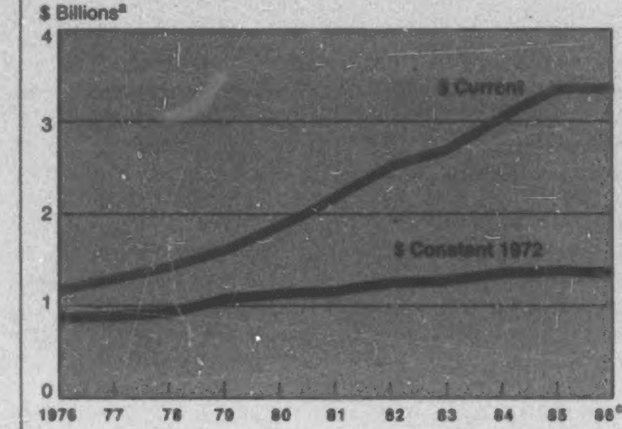
According to Commerce Department surveys, capital spending overseas by U.S. chemical companies also will pick up in 1986, after being unchanged in 1985. The latest government tabulation of overseas spending on new plant and equipment by wholly owned affiliates of U.S. chemical companies shows such expenditures rising 23% in 1986 to $3.2 billion, the highest level ever. For all manufacturing, the increase will be 13% to about $17.3 billion.

CHEMICAL CAPITAL SPENDING: Companies plan moderate increases for 1986

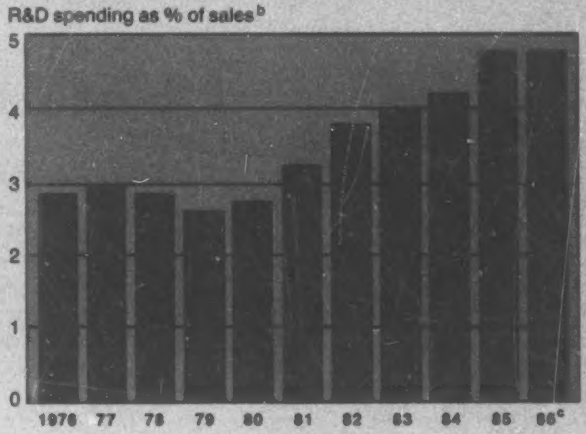
$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Air Products	$ 402	$ 392	$ 263	$ 246	$ 347	$ 323	$ 364	$ 246	$ 200	$ 143	$ 162
American Cyanamid	200	203	200	165	171	181	196	235	251	235	232
Celanese	200	159	275	105	275	414	253	245	248	243	223
Dow Chemical	900	806	781	630	829	1176	1184	1268	1075	1163	1200
Du Pont[b]	1600	1515	1319	1276	1300	1420	1297	864	714	704	876
Ethyl	135	90	103	85	92	141	156	123	96	88	88
W. R. Grace	390	348	380	353	560	657	658	514	313	279	234
Hercules	215	234	218	168	174	167	229	186	116	127	150
Monsanto	525	645	614	560	673	668	781	566	480	607	647
Olin	110	154	165	123	129	186	172	161	163	208	166
PPG Industries	455	452	315	450	452	376	401	252	261	212	177
Rohm & Haas	200	159	124	72	126	182	93	68	66	79	110
Union Carbide	675	649	670	761	1179	1186	1129	831	688	805	965
TOTAL	**$6007**	**$5806**	**$5427**	**$4994**	**$6307**	**$7077**	**$6913**	**$5559**	**4671**	**4893**	**5230**
ANNUAL CHANGE	**3%**	**7%**	**9%**	**−21%**	**−11%**	**2%**	**24%**	**19%**	**−5%**	**−6%**	**8%**

a Planned. b Excludes Conoco. **Note:** Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. **Source:** Company data

Chemical companies' R&D budgets will be flat this year . . .



. . . but spending will remain high relative to sales



a R&D spending by 14 basic chemical companies. b For 14 basic chemical companies. c Estimated.
Sources: Worldwide data for 14 U.S. basic chemical companies, Battelle Columbus Laboratories, C&EN estimates

With no solid prospect of an increase in sales this year, the U.S. chemical industry is holding the line on its spending for research and development, according to C&EN's survey of 13 basic chemical companies. Spending will be flat in 1986, ending two years of double-digit increases. Adjusted for anticipated inflation in R&D costs, spending actually will decline 4% from 1985.

This cautious budgeting does not signal a reversal of the industry's six-year-old renewal of emphasis on research. Companies will still be spending about 4.8% of sales on R&D this year, the same as in 1985 and far higher than the recent nadir of 2.7% reached in 1979. The industry is still firmly pledged to develop new, higher-value products. Last year's widespread retrenchments and the recognition that prices of commodity chemicals—the cash cows that fund R&D—are not likely to rise much anytime soon cannot be ignored, however, and so spending plans have been adjusted.

The outlook for 1986 R&D spending is also somewhat skewed by the large drop likely in Union Carbide's research budget. Much of the decrease is due to the company's divestiture this year of several large units. Even if 1985 spending is restated to exclude those units, however, Carbide's R&D budget for 1986 still is down 8%. On that basis, spending by the 13 companies still would be up only 2% on a current-dollar basis and would fall 2% after being adjusted for inflation.

CHEMICAL R&D SPENDING: Essentially no growth in 1986

$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Air Products	$ 60	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19
American Cyanamid	265	251	232	208	185	166	148	130	108	96	83
Celanese	105	103	94	85	100	104	94	92	83	77	70
Dow Chemical	600	547	507	492	460	404	314	269	232	203	188
Du Pont[b]	1030	1080	1000	875	775	647	591	509	461	367	353
Ethyl	47	47	40	39	39	37	34	29	25	28	25
W. R. Grace	100	92	81	73	64	57	45	42	37	32	28
Hercules	69	76	72	74	74	65	57	50	43	40	37
Monsanto	520	470	370	290	264	233	208	161	136	132	114
Olin	59	53	52	49	45	38	31	26	25	25	23
PPG Industries[c]	176	176	150	127	127	119	103	83	70	61	56
Rohm & Haas	125	124	109	100	92	77	67	54	49	45	43
Union Carbide[d]	191	275	265	245	240	207	166	161	156	156	143
TOTAL	$3347	$3345	$3016	$2697	$2502	$2186	$1838	$1630	$1448	$1286	$1182
ANNUAL CHANGE	0%	11%	12%	8%	14%	16%	16%	13%	13%	9%	9%

a Planned. b Excludes petroleum and coal segments. c Historical figures net of taxes and depreciation; 1986 estimated. d Company is divesting a substantial share of assets this year; restated on a continuing operations basis, 1985 R&D spending total was $207 million. **Sources:** Company data and estimates

INDUSTRY BALANCE SHEET: Liabilities rise considerably and stockholders' equity slips

Industrial chemicals and synthetics

Assets	1985	1984	Change
	($ billions)		
Current assets:			
Cash and U.S. bank deposits	$ 2.30	$ 1.10	109%
Short-term securities	1.13	1.29	−12
Receivables	13.65	13.07	4
Inventories	12.25	12.24	0
Other current assets	3.07	2.89	6
Total	**32.41**	**30.60**	**6**
Fixed assets			
Depreciable fixed assets	84.14	81.80	3
Land and mineral rights	3.60	3.44	5
Less: accumulated depreciation and depletion	43.97	41.34	6
Net fixed assets	**43.77**	**43.90**	**0**
Other assets, including investments and intangibles	**24.68**	**19.10**	**29**
TOTAL ASSETS	**$100.86**	**$93.61**	**8%**

Source: Bureau of the Census

Liabilities and stockholders' equity	1985	1984	Change
	($ billions)		
Current liabilities:			
Short-term debt	$ 3.98	$ 1.89	111%
Accounts payable	7.00	6.73	4
Accrued income taxes	1.11	1.44	−23
Current portion of long-term debt	1.14	1.26	−10
Other current liabilities	11.48	9.69	18
Total	**24.71**	**21.01**	**18**
Long-term debt	**22.38**	**18.12**	**24**
Other noncurrent liabilities, including deferred taxes and minority interest	**9.64**	**7.96**	**21**
TOTAL LIABILITIES	**56.73**	**47.09**	**20**
Stockholders' equity			
Capital stock and other capital	16.54	16.87	−2
Retained earnings	27.59	29.65	−7
TOTAL STOCKHOLDERS' EQUITY	**44.13**	**46.53**	**−5**
TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	**$100.86**	**$93.61**	**8%**

DEBT RATIOS: Up markedly last year from the low level of the previous year

$ Billions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	$22.4	$18.1	$19.4	$22.0	$21.4	$16.8	$14.8	$13.6	$12.3	$11.8	$10.2
Stockholders' equity	$44.1	$46.5	$45.3	$45.9	$42.5	$39.8	$32.3	$29.3	$26.3	$25.0	$22.8
Debt ratio[a]	33.6%	28.0%	30.0%	32.4%	33.5%	29.6%	31.4%	31.8%	31.9%	32.0%	30.8%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	$39.5	$33.8	$36.2	$38.2	$36.9	$28.3	$24.9	$23.5	$21.1	$19.4	$16.8
Stockholders' equity	$100.0	$100.3	$97.2	$95.3	$89.9	$79.5	$67.4	$60.8	$54.9	$50.8	$45.7
Debt ratio[a]	28.3%	25.2%	27.2%	28.6%	29.1%	26.3%	27.0%	27.9%	27.8%	27.6%	26.9%
ALL MANUFACTURING											
Long-term debt	$362.7	$324.2	$286.6	$293.1	$266.5	$236.2	$204.8	$182.0	$167.3	$153.6	$145.2
Stockholders' equity	$875.0	$883.6	$837.6	$783.0	$762.3	$699.7	$624.0	$560.8	$511.7	$475.3	$435.5
Debt ratio[a]	29.3%	26.8%	25.5%	27.2%	25.9%	25.2%	24.7%	24.5%	24.6%	24.4%	25.0%

[a] Long-term debt as a percentage of long-term debt plus stockholders' equity. **Note:** Because of changes in accounting rules and industry classifications, numbers over the entire range of years are not strictly comparable. **Source:** Bureau of the Census

CASH FLOW: A year of corporate restructuring changes the typical pattern

$ Millions, % of total	1985		1984		1983		1982		1981	
SOURCES OF FUNDS										
Net income	$ 991	6.3%	$ 3,917	29.5%	$ 2,735	21.5%	$ 2,347	19.4%	$ 3,629	17.1%
Depreciation and depletion	5,029	31.9	4,699	35.4	4,633	36.4	4,346	36.0	3,633	17.1
Deferred taxes	20	0.1	591	4.4	362	2.8	570	4.7	906	4.3
Other internal sources	7,271	46.1	2,496	18.8	2,591	20.4	1,841	15.2	1,308	6.1
Long-term debt	2,310	14.7	1,451	10.9	1,899	14.9	2,554	21.1	7,190	33.9
Stock	140	0.9	135	1.0	514	4.0	427	3.5	4,567	21.5
TOTAL	**$15,761**	**100.0%**	**$13,288**	**100.0%**	**$12,734**	**100.0%**	**$12,085**	**100.0%**	**$21,233**	**100.0%**
APPLICATIONS OF FUNDS										
Dividends	$ 1,940	12.3%	$ 1,891	14.2%	$ 1,754	13.8%	$ 1,682	13.9%	$ 1,569	7.4%
Capital expenditures	6,493	41.2	6,335	47.7	5,619	44.1	7,192	59.5	6,975	32.9
Additions to working capital	150	1.0	−16	−0.1	−343	−2.7	−1,548	−12.8	3,576	16.8
Reduction of long-term debt	2,829	17.9	2,649	19.9	3,380	26.6	3,398	28.1	1,081	5.1
Other applications	4,348	27.6	2,429	18.3	2,324	18.2	1,361	11.3	8,032	37.8
TOTAL	**$15,761**	**100.0%**	**$13,288**	**100.0%**	**$12,734**	**100.0%**	**$12,085**	**100.0%**	**$21,233**	**100.0%**

Note: Data are totals for 12 major chemical companies: American Cyanamid, Celanese, Dow Chemical, Du Pont, Ethyl, Hercules, Monsanto, Olin, Pennwalt, Rohm & Haas, Union Carbide, and Williams Cos. **Sources:** Company annual reports

2 Finances of the U.S. Chemical Industry

Last year was, at best, a standoff for the major U.S. producers of chemicals. Sales were lower for nearly as many companies as reported increased revenues. And earnings fell for almost twice as many companies as reported improved net income. Profitability, in fact, was especially hard hit in 1985. Among the 35 leading chemical companies for whom annual financial data are reported on this page and the three that follow, only about one in six reported a higher profit margin last year, and a mere one in seven chalked up an improvement in return on stockholders' equity.

For many companies, however, last year's financial results were severely affected by a host of unusual charges. The restructuring that many firms have undertaken in recent years in their attempt to streamline their operations, shuck off unpromising product lines, reduce staffs, and generally improve operating efficiency is especially evident in the asset write-downs, accounting changes, and other special charges taken against 1985 revenues. Dow Chemical, for one, wrote off a pretax $471 million in assets in its effort to cut back excess capacity, which was largely responsible for the 90% drop in its net income. Restructuring programs similarly cost Monsanto $341 million, after taxes, and Olin $230 million, pulling both companies into the red for the year. Likewise, Union Carbide's complex steps to restructure itself while fending off a hostile takeover attempt by GAF Corp., which included the sale of its consumer products businesses, drastically changed the company from what it had been a year earlier.

Explanation of table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but these items are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents and trademarks, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, and inventories but excluding prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Net worth. Equity at year's end of preferred and common stock holders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). **Per cent of sales:** net income divided by net sales. **Per cent of net worth:** net income divided by tangible net worth. **Dollars per share:** net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the calendar year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share.

Money figures in thousands of dollars unless otherwise indicated

								NET INCOME						
Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	% of sales	% of net worth	$ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
CHEMICALS														
Air Products & Chemicals														
1985[a]	$1,829,588	$143,484	$2,539,545	1.1	$1,782,267	$392,176	$1,109,068	7.8%	12.9%	$2.38	$0.635	2.3%	$68⅛–44½	11.9
1984[a]	1,735,115	140,618	2,267,457	1.1	1,587,382	262,401	1,058,328	8.1	13.3	2.28	0.525	2.5	24⅛–18⅛	9.3
1983[a]	1,634,246	108,963	2,160,157	1.1	1,541,345	246,417	988,256	6.7	11.0	1.78	0.45	2.1	25½–17	12.0
1982[a]	1,568,916	105,654[b]	2,118,882	1.2	1,497,162	346,680	867,565	6.7	12.2	1.84[b]	0.40	2.5	20½–11⅛	8.8
American Cyanamid Co.														
1985	$3,536,100	$120,200[c]	$3,383,400	2.0	$1,126,900	$202,600	$1,623,000	3.4%	7.4%	$2.50[c]	$1.90	3.5%	$59⅛–48	21.4
1984	3,856,726	215,918	3,304,027	1.9	1,241,927	200,110	1,645,122	5.6	13.1	4.41	1.86	3.9	53⅛–42⅛	10.8
1983	3,535,514	166,356	3,031,311	2.1	1,255,658	165,068	1,578,875	4.7	10.5	3.41	1.75	3.8	59–33⅝	13.6
1982	3,453,674	132,127	2,985,004	2.0	1,296,204	171,047	1,526,390	3.8	8.7	2.74	1.75	5.7	37½–24⅝	11.3
Betz Laboratories														
1985	$319,381	$36,792	$253,704	2.2	$137,255	$27,030	$194,793	11.5%	18.9%	$2.33	$1.26	3.7%	$38⅛–30⅛	14.7
1984	303,888	36,737	220,662	2.1	123,296	25,302	170,684	12.1	21.5	2.33	1.10	3.3	39–27⅛	14.2
1983	266,983	33,100	204,174	2.1	110,872	32,795	161,766	12.4	20.5	2.08	0.94	2.4	44⅝–32⅛	18.5
1982	254,717	30,561	186,320	2.0	87,382	24,769	143,421	12.0	21.3	1.93	0.82	2.4	42⅛–24⅝	17.4
Big Three Industries														
1985	$834,170	$14,537[d]	$1,066,832	2.4	$756,564	$76,044	$511,546	1.7%	2.8%	$0.38[d]	$0.82	3.5%	$28⅝–19⅛	61.2
1984	775,678	56,696	1,152,791	2.1	820,807	96,897	506,272	7.3	10.0	1.40	0.80	3.7	24⅞–18⅛	15.4
1983	668,841	45,331	1,097,602	3.0	763,863	71,581	615,720	6.8	7.4	1.07	0.74	3.2	27⅝–18½	21.6
1982	767,785	86,812	1,055,313	3.0	773,777	162,293	609,792	11.3	14.2	2.05	0.72	3.3	28½–15⅛	10.6

a Fiscal year ends Sept. 30. b Excludes extraordinary gain for debt-to-equity exchange of $2.8 million ($0.05 per share) and credit for cumulative effect of change in accounting principle for investment tax credit of $61.9 million ($2.16 per share). c From continuing operations; excludes net income and gain on sale of Formica Brand Products Group of $8.9 million ($0.18 per share). d Includes special charge for inventory and equipment write-down of $42.3 million ($1.10 per share).

Money figures in thousands of dollars unless otherwise indicated

								NET INCOME						
Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	% of sales	% of net worth	$ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
Cabot Corp.														
1985[a]	$1,407,516	$71,290[b]	$1,573,086	1.9	$ 623,211	$141,559	$604,085	5.1%	11.8%	$2.22[b]	$0.92	3.4%	$33¾–20½	12.2
1984[a]	1,752,523	97,073	1,730,722	1.8	1,051,251	116,911	699,167	5.5	13.9	3.02	0.92	3.6	28⅞–22⅝	8.5
1983[a]	1,558,016	64,162	1,293,340	2.6	656,894	76,964	658,838	4.1	9.7	2.00	0.92	3.6	30⅞–20½	12.8
1982[a]	1,587,658	88,007	1,300,553	2.2	664,434	138,342	624,060	5.5	14.1	2.77	0.92	4.4	25½–16⅝	7.5
Celanese Corp.														
1985	$3,046,000	$178,000	$2,809,000	1.3	$1,217,000	$159,000	$1,017,000	5.8%	17.5%	$13.70	$4.50	3.9%	$151–79⅝	8.4
1984	3,328,000	161,000	3,104,000	1.6	1,349,000	169,000	1,099,000	4.8	14.6	10.87	4.10	5.7	82–62⅝	6.7
1983	3,261,000	112,000	2,869,000	1.7	1,445,000	105,000	1,169,000	3.4	9.6	6.69	4.00	6.4	79⅝–45	9.1
1982	3,062,000	(34,000)[c]	2,862,000	1.9	1,608,000	275,000	1,131,000	—	—	(2.45)[c]	4.00	7.9	59⅞–41⅛	—
Chemed Corp.														
1985	$372,677	$21,858	$197,615	1.7	$42,002	$7,874	$58,234	5.9%	37.5%	$2.40	$1.52	5.1%	$33⅝–25⅝	11.9
1984	346,140	20,110	180,518	1.7	45,517	9,198	49,822	5.8	40.4	2.29	1.48	4.7	36⅝–25¾	13.6
1983	271,343	17,371[d]	174,248	1.9	35,012	5,703	58,420	6.4	29.7	2.17[d]	1.36	3.8	39⅝–32	16.4
1982	249,019	16,824[e]	152,735	1.7	30,887	5,008	36,448	6.8	46.2	1.79[e]	1.25	4.7	36–17⅝	14.9
Crompton & Knowles Corp.														
1985	$231,225	$7,575	$120,076	2.5	$30,376	$3,362	$63,839	3.3%	11.9%	$2.20	$1.20	5.3%	$27⅛–18⅝	10.3
1984	230,434	7,891	114,135	2.5	30,809	3,917	59,586	3.4	13.2	2.31	1.14	5.3	23¾–19¼	9.3
1983	230,560	6,302	115,536	2.6	31,205	2,954	57,893	2.7	10.9	1.81	1.06	4.6	28⅞–16⅝	12.6
1982	213,250	5,199	117,902	2.6	33,055	3,582	59,320	2.4	8.8	1.44	1.04	6.6	19⅝–12⅛	9.1
Dow Chemical Co.														
1985	$11,537,000	$ 58,000	$11,565,000	1.5	$5,127,000	$806,000	$4,527,000	0.5%	1.3%	$0.31	$1.80	5.2%	$41⅞–27	111.1
1984	11,418,000	549,000[f]	11,217,000	1.5	5,173,000	781,000	4,860,000	4.8	11.3	2.83	1.80	6.0	34½–25⅝	10.6
1983	10,951,000	293,000[g]	11,785,000	1.4	5,695,000	630,000	4,851,000	2.7	6.0	1.50[g]	1.80	5.7	38⅝–25	21.1
1982	10,618,000	342,000[h]	11,612,000	1.8	5,961,000	829,000	4,845,000	3.2	7.1	1.77[h]	1.80	7.4	28⅞–19⅝	13.7
E. I. du Pont de Nemours & Co.														
1985	$29,483,000	$1,118,000	$25,140,000	1.6	$15,195,000	$3,046,000	$12,659,000	3.8%	8.8%	$4.61	$3.00	5.1%	$69⅝–47⅝	12.7
1984	35,915,000	1,431,000	24,098,000	1.6	14,409,000	2,931,000	12,233,000	4.0	11.7	5.93	2.90	6.1	52⅞–42⅝	8.0
1983	35,378,000	1,127,000	24,432,000	1.7	14,261,000	2,628,000	11,472,000	3.2	9.8	4.70	2.50	5.5	55–35½	9.8
1982	33,331,000	894,000	24,343,000	1.7	14,004,000	3,295,000	10,850,000	2.7	8.2	3.75	2.40	6.5	44⅝–30	9.9
Ethyl Corp.														
1985	$1,547,034	$117,146	$1,509,988	2.0	$557,256	$ 89,512	$754,853	7.6%	15.5%	$0.92	$0.285	2.5%	$15⅛–7⅞	12.6
1984	1,675,059	132,184	1,437,207	2.2	573,156	103,416	707,716	7.9	18.7	0.86	0.21	3.2	8⅛–5	7.7
1983	1,745,193	106,038	1,449,982	2.0	626,461	84,723	811,260	6.1	13.1	0.65	0.21	3.9	7⅛–3⅝	8.4
1982	1,614,626	94,166	1,458,534	2.2	666,186	91,915	766,175	5.8	12.3	0.50	0.19	5.7	4⅛–2⅛	5.6
Ferro Corp.														
1985	$651,071	$11,163[i]	$391,133	2.0	$145,651	$27,050	$193,850	1.7%	5.8%	$1.66	$1.20	3.9%	$ 37–24⅛	18.4
1984	662,867	16,886	359,938	2.0	136,462	29,364	185,983	2.5	9.1	2.53	1.20	4.0	38½–22¼	12.0
1983	619,179	19,228	364,861	1.9	132,509	20,252	185,337	3.1	10.4	3.04	1.20	3.7	39⅞–24⅝	10.6
1982	595,830	10,227[j]	345,922	2.0	133,318	22,650	161,945	1.7	6.3	1.37[j]	1.20	4.9	30½–18½	17.9
First Mississippi Corp.														
1985[k]	$273,185	$18,230[l]	$395,435	1.5	$234,574	$63,257	$180,787	6.7%	10.1%	$0.90[l]	$0.24	2.8%	$11⅝–6⅝	10.1
1984[k]	270,004	15,845[m]	380,855	1.5	209,742	41,034	166,957	5.9	9.5	0.77[m]	0.24	2.3	13¾–7⅛	13.6
1983[k]	203,976	14,146	379,436	1.3	200,990	47,428	155,055	6.9	9.1	0.69	0.24	2.0	15½–8⅛	17.2
1982[k]	222,977	23,212[n]	304,587	1.0	183,904	67,882	145,407	10.4	16.0	1.11[n]	0.24	2.2	16–6	9.9
GAF Corp.														
1985	$731,962	$54,290[o]	$879,174	1.7	$194,086	$47,161	$298,153	7.4%	18.2%	$1.57[o]	$0.10	0.4%	$ 35–12⅛	15.0
1984	731,314	41,406[p]	452,273	2.2	159,115	17,900	214,006	5.7	19.3	1.31[p]	0.05	0.5	12⅞–7½	7.8
1983	699,397	24,189[q,r]	414,267	1.7	164,468	13,904	169,804	—	—	(1.11)[q,r]	0.025	0.3	9⅞–6½	—
1982	623,236	12,182[s]	468,332	1.6	192,400	17,713	181,900	2.0	6.7	0.32[s]	0.25	4.2	7⅝–4⅝	18.7
W. R. Grace & Co.														
1985	$5,193,000	$127,800[t]	$5,287,800	1.9	$2,596,000	$348,000	$2,271,400	2.5%	5.6%	$2.45[t]	$2.80	6.8%	$49½–35½	17.3
1984	6,727,800	195,600	5,193,900	1.6	2,704,200	380,100	2,063,300	2.9	9.5	4.02	2.80	6.7	46⅞–36⅜	10.4
1983	6,219,500	159,700[u]	4,946,600	1.6	2,715,400	353,100	2,094,300	2.6	7.6	3.28[u]	2.80	6.3	56⅝–38⅜	13.5
1982	6,127,800	319,500[v]	4,854,300	1.7	2,706,400	569,500	2,136,600	5.2	15.0	6.62[v]	2.70	7.2	46¼–29½	5.6

a Fiscal year ends Sept. 30. b From continuing operations; excludes net loss from discontinued operations of $12.7 million ($0.39 per share) and provision for net loss on disposal of discontinued operations of $145.0 million ($4.53 per share). c Net loss; includes special charge related to 40% equity in Mexican affiliate of $39 million ($2.50 per share). d Excludes net gain on disposition of discontinued Dearborn Group operations of $875,000 ($0.11 per share). e Excludes net income from discontinued Dearborn Group operations of $1.9 million ($0.11 per share). f Includes pretax gain on sales of investments of $183 million but excludes tax benefit from realization of foreign tax loss carry-forwards of $36 million ($0.19 per share). g Includes pretax gain on sales of investments of $101 million but excludes extraordinary net gain on debt-for-equity exchange of $41 million ($0.21 per share). h Includes pretax gain on sales of investments of $214 million but excludes extraordinary net gain on debt-for-equity exchange of $57 million ($0.20 per share). i Excludes net loss on sale of Productol Chemical Division of $2.3 million ($0.34 per share). j Includes net loss on divestitures of $1.9 million ($0.23 per share). k Fiscal year ends June 30. l Excludes net gain from disposal of FirstMiss subsidiary of $900,000 ($0.04 per share). m Excludes net gain from disposal of FirstMiss subsidiary of $120,000 ($0.01 per share). n From continuing operations; excludes net loss from discontinued FirstMiss subsidiary of $8.4 million ($0.30 per share). o Excludes extraordinary credits of $23.3 million ($0.68 per share). p Excludes extraordinary credits of $15.7 million ($0.54 per share). q Excludes extraordinary credits of $25.4 million ($0.88 per share). r Deficit. s Excludes extraordinary credits of $38.7 million ($1.35 per share) and income from discontinued operations of $5.3 million ($0.19 per share). t From continuing operations; excludes net income from discontinued retail operations of $19.1 million ($0.37 per share). u Includes net gains on disposal of businesses of $5.7 million. v Includes gain on restructuring Chemed Corp. of $65.1 million and net losses on disposal of businesses of $800,000.

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
Great Lakes Chemical Corp.														
1985	$276,932	$28,818	$314,423	2.2	$137,710	$21,344	$186,718	10.4%	15.4%	$1.93	$0.44	1.2%	$44½–31⅛	18.6
1984	278,235	35,568	276,468	2.2	130,704	28,770	164,605	12.8	21.6	2.38	0.36	1.1	38⅝–24	13.2
1983	225,950	23,842	217,916	2.1	121,411	23,383	132,286	10.6	18.0	1.63	0.30	1.1	39⅝–16⅝	17.3
1982	169,703	13,945	192,127	2.2	113,650	19,143	111,782	8.2	12.5	0.96[a]	0.28	1.6	20⅛–12½	16.9
Hercules														
1985	$2,587,213	$133,161	$2,658,822	2.5	$1,000,212	$234,240	$1,474,201	5.1%	9.0%	$2.40	$1.60	4.5%	$40⅝–31⅛	15.0
1984	2,570,965	197,185	2,308,489	2.4	906,031	218,105	1,366,911	7.7	14.4	3.54	1.48	4.5	38–27⅞	9.2
1983	2,620,954	174,222	2,175,173	2.1	793,313	167,993	1,288,118	6.6	13.5	3.17	1.38	3.9	43½–27⅛	11.1
1982	2,468,971	86,861[f]	2,001,354	2.2	923,676	164,937	1,078,911	3.5	8.1	1.97[f]	1.32	5.8	28⅝–16⅞	11.6
International Flavors & Fragrances														
1985	$501,046	$69,698	$559,855	4.2	$159,298	$22,134	$426,986	13.9%	16.3%	$1.89	$1.12	3.4%	$ 40–28	17.5
1984	476,678	69,242	452,392	4.4	140,109	20,942	351,183	14.5	19.7	1.88	1.08	4.1	29½–22⅞	13.8
1983	460,945	68,410	458,262	3.5	139,921	26,851	344,255	14.8	19.9	1.87	1.04	3.5	35⅝–23⅝	15.9
1982	447,869	63,160	431,589	4.1	135,565	28,369	335,902	14.1	18.8	1.73	1.01	4.3	30–17⅝	13.7
International Minerals & Chemical Corp.														
1985[b]	$1,627,300	$119,600	$1,957,200	2.0	$2,144,300	$116,000	$1,092,000	7.3%	11.0%	$4.39	$2.60	6.0%	$ 44–34⅛	8.9
1984[b]	1,532,900	112,000[c]	1,965,600	1.9	2,061,400	104,800	1,039,100	7.3	10.8	4.17[c]	2.60	6.4	40–32⅞	8.8
1983[b]	1,462,000	80,500	1,943,900	1.9	1,983,700	119,300	1,024,100	5.5	7.9	3.02	2.60	6.5	40–31⅝	13.3
1982[b]	1,560,400	122,300[d]	1,941,900	1.8	1,869,900	161,600	1,010,200	7.8	12.1	4.56[d]	2.60	8.6	36⅞–23½	6.6
Lawter International														
1985	$96,769	($5,413)[e,j]	$84,030	3.4	$22,702	$3,179	$47,588	—	—	($0.31)[e,j]	$0.56	4.7%	$13½–10⅝	—
1984	98,404	14,862	77,877	4.8	21,146	3,339	58,370	15.1%	25.5%	0.86	0.55	4.4	14½–10½	14.5
1983	90,020	14,340	75,615	4.4	21,066	3,345	55,785	15.9	25.7	0.83	0.49	4.6	14⅛–7⅛	12.8
1982	80,029	10,021	63,967	5.1	20,587	4,293	52,387	12.5	19.1	0.58	0.48	6.0	8⅛–5⅝	12.0
Liquid Air Corp.														
1985	$543,041	$31,753	$599,281	1.2	$418,165	$103,675	$289,819	5.8%	11.0%	$2.42	$1.60	6.8%	$27⅝–19½	9.8
1984	501,735	27,304	549,821	1.8	370,530	62,461	246,667	5.4	11.1	2.07	1.60	7.7	23–18⅛	10.0
1983	459,400	23,902	500,573	1.5	354,796	41,620	244,849	5.2	9.8	1.80	1.60	7.2	26⅛–18½	12.4
1982	448,996	27,512	503,090	1.8	353,376	58,657	247,801	6.1	11.1	2.13	1.60	9.1	20⅝–14⅝	8.3
Loctite Corp.														
1985[b]	$231,479	$20,443	$215,482	1.9	$49,793	$11,278	$121,918	8.8%	16.8%	$2.24	$0.80	2.5%	$ 37–27	14.3
1984[b]	241,744	26,349	223,694	2.0	45,696	6,172	129,526	10.9	20.3	2.67	0.64	1.7	42¾–30⅝	13.7
1983[b]	215,892	17,128	209,387	2.2	46,789	9,955	129,419	7.9	13.2	1.72	0.56	1.5	46½–28⅛	21.8
1982[b]	216,450	15,778	196,069	2.4	44,083	10,824	119,752	7.3	13.2	1.59	0.56	2.3	30⅝–18⅝	15.4
Lubrizol Corp.														
1985	$903,403	$60,224	$854,445	2.4	$290,298	$39,498	$519,298	6.7%	11.6%	$1.49	$1.16	4.8%	$28⅞–19⅝	16.3
1984	831,681	67,731	701,974	2.8	251,735	29,490	474,343	8.1	14.3	1.73	1.12	5.2	24½–18⅛	12.4
1983	789,546	64,744[g]	682,864	2.8	274,337	25,003	471,521	8.2	13.7	1.65[g]	1.08	4.7	27⅞–18⅛	13.9
1982	801,284	47,561	643,744	2.6	288,504	51,589	462,044	5.9	10.3	1.21	1.08	5.7	23⅝–14⅛	15.7
Monsanto Co.														
1985	$6,747,000	($128,000)[e,h]	$6,678,000	1.1	$3,034,000	$645,000	$1,208,000	—	—	($1.67)[e,h]	$2.45	5.1%	$55⅝–40⅝	—
1984	6,691,000	439,000	6,250,000	2.0	3,374,000	614,000	3,511,000	6.6%	12.5%	5.42	2.25	4.8	53⅞–40⅝	11.5
1983	6,299,000	369,000[i]	6,427,006	2.1	3,284,000	560,000	3,667,000	5.9	10.1	4.48[i]	2.075	4.4	58½–37⅛	10.6
1982	6,325,000	329,000[i]	6,077,000	2.4	3,313,000	673,000	3,490,000	5.2	9.4	4.10[i]	1.975	5.4	44½–28⅛	8.9
Morton Thiokol														
1985[b]	$1,832,300	$119,500[k]	$1,173,900	1.8	$560,700	$117,000	$510,500	6.5%	23.4%	$2.44[k]	$0.63	1.9%	$40½–28	13.8
1984[b]	2,001,508	109,759	1,152,082	1.5	526,713	90,859	469,545	5.5	22.4	2.17	0.57	2.2	31½–20	11.9
1983[b]	1,509,157	78,462	1,002,848	1.3	522,938	70,944	401,952	5.2	19.5	1.72	0.53	2.4	28⅞–16½	12.8
1982[b]	786,976	48,499[l]	734,801	2.1	206,813	37,804	371,753	6.2	13.0	1.20	0.51	3.7	18⅝–9⅛	11.6
Nalco Chemical Co.														
1985	$682,333	$73,332	$492,998	1.8	$247,912	$59,905	$335,685	10.7%	21.8%	$1.87	$1.20	4.8%	$28⅝–22	13.5
1984	664,303	73,080[m]	471,543	2.4	205,103	52,478	344,392	11.0	21.2	1.80[m]	1.20	4.4	33⅛–21	14.6
1983	659,403	71,000	487,010	2.3	191,791	40,505	348,386	10.8	20.4	1.78	1.14	3.5	37–28	18.3
1982	643,863	64,350[n]	464,868	2.2	194,450	56,241	336,488	10.0	19.1	1.62[n]	1.12	4.3	34–18	16.0
Olin Corp.														
1985	$1,751,106	($190,308)[e,o]	$1,516,096	1.6	$718,371	$154,499	$804,844	—	—	($8.28)[e,o]	$1.50	4.9%	$ 38–28⅝	—
1984	2,065,328	88,747	1,822,099	1.9	860,658	106,000	867,307	4.3%	10.2%	3.81	1.385	4.7	32½–25⅛	7.7
1983	1,934,579	71,715	1,829,416	1.9	850,936	122,580	848,355	3.7	8.5	3.01	1.23	4.3	34–23	9.5
1982	1,823,137	62,800[p]	1,636,027	1.7	839,974	139,015	805,185	3.4	7.8	2.60[p]	1.20	5.7	28⅛–15½	7.8

a Excludes extraordinary net gain on debt-for-equity exchange of $11.6 million ($0.25 per share). b Fiscal year ends June 30. c Excludes net loss from operations and disposal of discontinued methanol joint venture of $30.3 million ($1.13 per share). d From continuing operations; excludes earnings and net gain on disposal of discontinued chemical operations of $15.1 million ($0.57 per share). e Deficit. f Includes one-time tax provision for future repatriation of foreign earnings of $14.0 million ($0.80 per share). g Includes net gain on sale of investments of $7.5 million ($0.19 per share). h Includes special charge for restructuring costs, before taxes, of $557 million but excludes net gain from repayment of debt of $30 million ($0.40 per share). i Excludes extraordinary net tax benefits from utilization of ex-U.S. loss carry-forwards of $33 million ($0.41 per share). j Excludes extraordinary net gain on debt-for-equity exchange of $23 million ($0.29 per share). k From continuing operations; excludes net income from discontinued Texsize division operations of $3.3 million ($0.06 per share) and net gain on sale of the division of $75.1 million ($1.51 per share). l From continuing operations; excludes net income from discontinued operations of $8.2 million ($0.61 per share) and net gain on sale of pharmaceuticals business of $79.8 million ($5.92 per share). m Excludes net income from discontinued lead antiknock compounds operations of $3.1 million ($0.08 per share). n Excludes net loss on discontinued Industrial Bio-Test Laboratories operations of $6.2 million ($0.16 per share). o From continuing operations; includes special charge for restructuring costs, before taxes, of $330.0 million but excludes net income and net gain on sale of Ecusta paper and film businesses of $24.9 million ($1.09 per share). p Excludes special charge for DDT claims, net, of $9.5 million ($0.40 per share).

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
Pennwalt Corp.														
1985	$1,013,308	$11,219[a]	$937,672	1.5	$433,867	$99,691	$323,263	1.1%	3.5%	$0.05[a]	$2.20	5.0%	$44½–34	785.0
1984	1,047,214	45,356	868,673	1.9	393,765	87,177	485,325	4.3	9.3	3.31	2.20	6.0	42⅛–31½	11.1
1983	976,741	44,796[b]	851,982	2.6	348,190	69,808	458,077	4.6	9.8	3.50[b]	2.20	5.9	45⅝–29	10.4
1982	952,400	24,562[c]	737,048	1.6	342,785	76,486	346,384	2.6	7.1	2.37[c]	2.20	7.8	34⅞–21½	11.9
Reichhold Chemicals														
1985	$822,534	($28,432)[d,e]	$451,903	1.2	$203,972	$35,057	$134,714	—	—	($3.85)[d,e]	$0.80	2.2%	$43⅛–29⅝	—
1984	801,355	25,709	371,619	2.0	172,219	24,228	206,421	3.2%	12.5%	3.03	0.65	2.2	35⅝–23	7.5
1983	747,263	21,700	382,273	2.0	175,722	19,305	211,081	2.9	10.3	2.74	0.51	1.8	38⅞–18⅛	10.4
1982	814,911	6,875[f]	364,133	2.5	159,181	29,516	200,546	0.8	3.4	0.57[f]	0.48	3.2	19⅝–10	26.0
Rohm & Haas Co.														
1985	$2,051,000	$141,000[g]	$1,619,000	2.0	$581,000	$150,000	$821,000	6.9%	17.2%	$2.01[g]	$0.70	3.1%	$26⅛–18⅝	11.1
1984	2,042,011	172,219[h]	1,540,570	2.0	555,945	134,253	872,687	8.4	19.7	2.24[h]	0.60	3.1	23⅛–16	8.7
1983	1,875,937	137,603	1,489,815	2.7	518,360	71,534	882,984	7.3	15.6	1.78	0.50	2.5	27–12⅝	11.1
1982	1,828,027	85,605[i]	1,365,163	2.5	546,623	125,927	807,853	4.7	10.6	1.11[i]	0.47	4.5	13⅛–7⅝	9.4
Stepan Co.														
1985	$235,919	$5,471	$139,307	1.5	$82,796	$19,189	$49,575	2.3%	11.0%	$1.89	$0.60	3.5%	$23⅛–16⅝	10.5
1984	234,930	5,423[j]	133,941	1.6	73,261	11,557	47,660	2.3	11.4	1.66[j]	0.65	3.9	18⅝–14½	10.0
1983	207,074	6,337	144,997	1.5	76,044	9,804	58,450	3.1	10.8	1.75	0.58	3.9	17½–12	8.4
1982	208,373	5,303	163,326	1.3	75,475	16,148	55,067	2.5	9.6	1.45	0.56	4.1	18⅛–9⅛	9.4
Sun Chemical Corp.														
1985	$883,864	$ 4,069[k]	$666,118	1.4	$202,984	$45,196	$187,735	0.5%	2.2%	$0.52[k]	$0.48	1.4%	$ 39–28⅝	64.8
1984	872,948	25,218	587,932	2.0	178,292	38,052	174,164	2.9	14.5	3.23	0.48	1.7	33–24⅛	8.9
1983	746,609	9,529	497,715	1.8	141,771	27,666	157,917	1.3	6.0	1.24	0.48	2.0	30⅝–17⅞	19.6
1982	664,257	14,871[l]	523,799	1.9	134,351	27,371	162,130	2.2	9.2	1.97[l]	0.48	2.6	24⅛–13⅛	9.5
Union Carbide Corp.														
1985[m]	$8,596,000	($38,000)[d]	$ 8,461,000	1.3	$4,927,000	$ 649,000	$ 519,000	—	—	($0.38)[d]	$1.13	6.1%	$24⅝–12	—
1984	9,508,000	341,000[n]	10,402,000	1.8	6,383,000	670,000	4,808,000	3.6%	7.1%	1.61[n]	1.13	6.9	21⅝–10⅞	10.1
1983	9,001,000	218,000[o]	10,226,000	1.8	6,282,000	761,000	4,860,000	2.4	4.5	1.04[o]	1.13	5.4	24⅝–17	20.1
1982	9,061,000	310,000	10,552,000	1.9	6,356,000	1,179,000	5,095,000	3.4	6.1	1.49	1.13	6.7	20⅝–13⅝	11.3
Williams Cos.														
1985	$3,139,600	$ 31,600	$4,337,400	0.9	$2,706,400	$259,000	$1,212,800	1.0%	2.6%	$0.92	$1.40	4.7%	$32⅞–20⅝	32.3
1984	3,388,700	144,500[p]	4,534,000	1.0	3,252,800	262,000	1,284,000	4.3	11.3	4.21[p]	1.25	4.6	31½–23	6.5
1983	2,167,000	54,000	4,686,400	0.7	3,193,000	253,400	1,173,900	2.5	4.6	1.79	1.20	5.1	30⅛–16⅝	13.1
1982	1,691,315	29,682[q]	2,369,791	1.7	1,513,712	171,895	1,029,411	1.8	2.9	1.00[q]	1.20	5.6	29⅝–13⅛	21.2
Witco Corp.														
1985	$1,448,929	$56,774	$794,308	2.3	$360,950	$71,083	$399,486	3.9%	14.2%	$3.85	$1.48	4.0%	$41⅛–33	9.7
1984	1,495,831	62,602	739,488	2.2	348,740	65,720	358,497	4.2	17.5	4.28	1.40	4.2	39½–27⅝	7.8
1983	1,385,744	52,022	715,472	2.1	313,794	44,901	319,334	3.8	16.3	3.60	1.26	4.6	37⅛–17⅝	7.6
1982	1,305,418	29,842	643,911	2.2	291,914	54,130	281,013	2.3	10.6	2.10	1.20	7.2	19⅝–13⅝	8.8
PHARMACEUTICALS														
Abbott Laboratories														
1985	$3,360,273	$465,335	$3,468,373	1.9	$1,368,542	$292,900	$1,870,663	13.8%	24.9%	$3.88	$1.40	2.5%	$ 72–38⅞	14.4
1984	3,103,962	402,575	3,172,897	1.7	1,236,572	334,800	1,602,700	13.0	25.1	3.34	1.20	2.8	49⅝–36⅝	12.8
1983	2,927,873	347,617	2,824,128	1.7	1,069,200	311,800	1,417,883	11.9	24.5	2.86	1.00	2.2	53⅝–36⅛	15.6
1982	2,602,447	289,123	2,566,909	1.1	901,058	266,600	1,310,886	11.1	22.1	2.37	0.84	2.5	41⅛–25⅝	14.1
American Home Products Corp.														
1985	$4,684,742	$717,140	$3,201,746	3.3	$859,414	$179,347	$2,098,293	15.3%	34.2%	$4.70	$2.90	5.0%	$68⅞–50⅛	12.4
1984	4,485,470	655,828[r]	2,849,732	3.3	769,623	141,801	1,905,733	14.6	34.4	4.29[r]	2.64	5.2	55⅝–46⅝	12.0
1983	4,856,501	627,233	2,864,104	2.0	812,370	204,680	1,826,964	12.9	34.3	4.00	2.40	5.0	54⅛–41⅝	12.0
1982	4,582,096	566,103	2,602,346	2.6	725,352	153,812	1,614,192	12.2	34.7	3.59	2.15	5.3	46–33⅛	11.3
Baxter Travenol Laboratories														
1985	$2,335,000	$137,000	$6,839,000	1.8	$1,682,000	$198,000	$2,953,000	5.9%	4.6%	$0.85	$0.37	2.5%	$18⅝–12½	17.2
1984	1,800,422	145,147[s]	2,000,753	1.5	767,836	171,652	1,106,731	8.1	13.1	1.03[s]	0.33	1.8	24⅞–11⅝	17.8
1983	1,842,544	218,055	2,127,037	1.6	746,304	192,464	1,151,109	11.8	18.9	1.54	0.28	1.1	31⅛–20	16.6
1982	1,671,445	186,885	1,792,710	1.9	628,720	148,812	1,061,009	11.2	17.6	1.32	0.23	1.1	25⅛–15⅛	15.4

a From continuing operations; includes special charge for restructuring program, before taxes, of $38.6 million but excludes net loss from operations and on disposal of discontinued dental businesses of $30.9 million ($2.80 per share). b Includes gain on sale, retirement, and revaluation of assets, before taxes, of $21.7 million. c From continuing operations; excludes provision for loss on disposal of discontinued operations of $2.8 million ($0.27 per share). d Deficit. e Includes special charge for restructuring program, before taxes, of $39.6 million. f Excludes net loss resulting from asset redeployment/divestiture program of $2.2 million ($0.32 per share). g Includes net gain on disposal of assets of $4.6 million ($0.07 per share). h Includes net gain on sale of oil and gas properties of $3.6 million ($0.05 per share). i Includes net gain on shutdown and disposal of assets of $10.4 million ($0.40 per share). j Includes nonrecurring net loss on writedown of equipment of $2.6 million. k Includes loss on disposal of assets, before taxes, of $9.1 million. l From continuing operations; excludes equity in net loss of affiliate's discontinued operations of $12.9 million ($1.71 per share). m Pro forma, after adjustment for repurchase of common stock, sale of consumer products businesses, special charges for restructuring program, and other special gains and losses. n Excludes extraordinary charge related to accident in Bhopal, India, of $18 million ($0.08 per share). o Excludes nonrecurring net charge for closing of facilities of $139 million ($0.66 per share). p Excludes net loss from operations and net gain on disposition of Edgcomb Metals Co. operations of $5.0 million ($0.15 per share). q From continuing operations; excludes net income from discontinued operations of $4.7 million ($0.15 per share). r From continuing operations; excludes net income from operations and net gain on sale of discontinued businesses of $76.3 million ($0.50 per share). s Excludes special net charge for closing three plants and revaluation of assets of $116.1 million ($0.82 per share).

2 Finances of the U.S. Chemical Industry

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
Bristol-Myers Co.														
1985	$4,444,000	$531,400	$3,557,300	2.3	$925,800	$222,000	$2,287,100	12.0%	23.2%	$3.86	$1.81	3.1%	$68½-49	15.2
1984	4,189,400	472,400	3,100,800	2.4	791,100	191,600	1,998,100	11.3	23.6	3.45	1.50	3.2	52⅝-41	13.6
1983	3,917,000	408,000	2,888,300	2.2	701,700	165,000	1,788,900	10.4	22.8	3.00	1.16	2.9	47⅞-31⅛	13.2
1982	3,599,900	348,700	2,665,800	2.2	653,600	170,000	1,624,000	9.7	21.5	2.59	1.02	3.3	37-25⅜	12.0
Eli Lilly & Co.														
1985	$3,270,600	$517,600	$3,859,400	1.7	$1,374,000	$207,100	$2,293,400	15.8%	22.6%	$3.69	$1.60	3.0%	$55⅞-32⅛	11.[illegible]
1984	3,109,200	490,200	3,556,500	1.6	1,280,400	205,300	2,133,800	15.8	23.0	3.36	1.49	4.9	33¾-26½	9.0
1983	3,033,700	457,400	3,401,200	1.7	1,212,600	199,900	2,108,400	15.1	21.6	3.06	1.375	4.4	34⅛-28⅛	10.2
1982	2,962,711	411,828	3,155,125	1.8	1,135,575	236,642	2,055,400	13.9	20.0	2.71	1.30	4.7	32⅜-22½	10.2
Merck & Co.														
1985	$3,547,500	$539,900	$4,805,100	1.9	$1,882,800	$237,600	$2,536,900	15.2%	21.3%	$3.79	$1.60	2.8%	$58⅞-45⅛	15.0
1984	3,559,665	492,967	4,489,697	1.9	1,912,778	274,425	2,443,260	13.8	20.2	3.35	1.50	3.4	48⅝-39⅛	13.1
1983	3,246,139	450,855	4,119,098	1.7	1,715,207	272,756	2,339,013	13.9	19.3	3.05	1.40	3.0	52⅞-40⅞	15.3
1982	3,063,017	415,137	3,501,652	1.9	1,557,490	295,106	2,147,988	13.6	19.3	2.80	1.40	3.7	44⅛-32	13.6
Pfizer														
1985	$4,024,500	$579,700	$4,341,500	2.1	$1,268,300	$195,800	$2,805,900	14.4%	20.7%	$3.44	$1.48	3.2%	$56⅛-37⅝	13.6
1984	3,854,500	507,900	3,927,700	2.1	1,155,600	144,000	2,365,100	13.2	21.5	3.08	1.32	3.7	42⅝-29⅝	11.6
1983	3,750,000	447,100	3,830,000	2.0	1,157,000	214,900	2,074,700	11.9	21.6	2.73	1.16	3.0	44⅜-33⅜	14.4
1982	3,453,600	332,800	3,644,500	1.9	1,124,700	265,500	1,869,500	9.6	17.8	2.13	0.92	2.8	40⅝-25	15.3
A. H. Robins Co.														
1985	$706,134	$61,414[a]	$620,710	3.7	$149,954	$23,150	($132,933)[c]	8.7%	—	$2.53	$0.00	—	$24⅜-5½	5.9
1984	631,891	(461,613)[b]	565,627	1.5	135,685	38,155	(210,353)[c]	--	—	(18.44)[b]	0.72	4.1%	23⅛-12⅛	—
1983	563,510	58,221[d]	459,462	3.1	107,651	20,955	305,636	10.3	19.0%	2.40	0.62	2.7	29⅝-18	9.5
1982	482,324	48,693[e]	386,843	3.8	98,079	15,815	267,945	10.1	18.2	1.90	0.52	3.3	20⅛-11⅛	7.9
Schering-Plough Corp.														
1985	$1,927,100	$192,600	$2,683,800	1.4	$991,800	$140,300	$1,389,600	10.0%	13.9%	$3.77	$1.68	3.3%	$66½-35⅛	13.5
1984	1,874,300	177,200	2,436,200	1.2	912,400	173,700	1,235,100	9.5	14.3	3.50	1.68	4.6	40-33	10.4
1983	1,808,500	178,500[f]	2,309,800	1.3	841,400	177,700	1,186,500	9.9	15.0	3.40[f]	1.68	4.0	48⅛-36⅝	12.5
1982	1,817,900	183,500	2,341,200	1.8	747,500	180,400	1,278,500	10.1	14.4	3.39	1.68	4.8	43⅝-26⅛	10.3
SmithKline Beckman Corp.														
1985	$3,256,600	$514,400	$3,534,500	1.8	$1,285,300	$248,000	$2,070,100	15.8%	24.8%	$6.56	$2.85	4.3%	$79⅝-52⅝	10.1
1984	2,[illegible]	500,300[g]	3,077,600	2.0	1,093,000	241,500	1,952,100	17.0	25.6	6.19[g]	2.80	5.1	60⅛-50	8.9
1983	2,[illegible]	485,990[h]	3,085,409	1.8	988,857	232,914	1,970,793	17.1	24.7	5.85[h]	2.65	4.0	76½-55⅛	11.3
1982	2,968,667	455,157	2,765,900	2.1	971,302	304,784	1,749,407	15.3	26.0	5.51	2.30	3.5	77⅝-57⅝	12.3
Squibb Corp.														
1985	$2,041,745	$226,599	$2,396,592	2.0	$701,439	$120,342	$1,409,382	11.1%	16.1%	$4.29	$1.72	2.0%	$82½-49⅝	15.7
1984	1,886,037	197,172	2,072,188	2.1	617,724	115,629	1,266,517	10.5	15.6	3.68	1.48	3.2	54⅜-37½	12.5
1983	1,768,801	173,274[i]	1,887,783	2.2	564,613	109,800	1,173,399	9.8	14.8	3.31[i]	1.365	2.8	55⅝-42⅞	14.9
1982	1,660,706	153,636	1,871,882	2.1	511,821	87,280	1,037,989	9.3	14.8	3.01	1.28	3.2	50½-29	13.2
Sterling Drug														
1985	$1,753,724	$153,310[j]	$1,588,991	2.0	$358,190	$74,176	$907,646	8.7%	16.9%	$2.56[j]	$1.19	3.5%	$41⅛-26⅝	13.3
1984	1,827,295	144,853[k]	1,429,618	2.5	370,273	73,158	894,943	7.9	16.2	2.30[k]	1.15	4.3	30-23½	11.2
1983	1,901,171	136,844	1,437,440	2.5	366,328	63,180	879,655	7.2	15.6	2.24	1.11	4.3	29⅝-22⅛	11.8
1982	1,796,153	131,970	1,297,989	2.6	356,535	89,068	825,944	7.3	16.0	2.17	1.06	4.3	29⅝-19⅝	11.4
Upjohn Co.														
1985	$2,008,486	$203,193[l]	$2,376,873	1.8	$852,054	$152,637	$1,295,085	10.1%	15.7%	$3.29[l]	$1.34	2.0%	$70⅝-33⅝	15.8
1984	2,179,060	173,272	2,248,363	1.5	809,534	136,738	1,134,154	8.0	15.3	2.83	1.28	4.4	36-22⅛	10.3
1983	1,986,106	160,225	2,195,048	1.9	754,954	155,016	1,057,288	8.1	15.2	2.64	1.175	4.1	34⅜-23⅛	10.9
1982	1,823,730	126,020	2,013,985	1.9	675,869	137,273	973,028	6.9	13.0	2.09	1.14	4.7	29⅝-18	11.6
Warner-Lambert Co.														
1985	$3,200,069	$237,704[m]	$2,286,187	1.2	$868,931	$138,774	$819,279	7.4%	29.0%	$3.05[m]	$1.50	3.2%	$49⅝-33⅝	13.6
1984	3,166,657	223,887	2,377,098	1.5	863,179	142,461	910,125	7.1	24.6	2.81	1.48	4.6	36⅛-28⅝	11.5
1983	3,108,325	200,496	2,363,879	1.7	826,232	165,854	869,980	6.5	23.0	2.51	1.42	4.7	35-25⅜	12.1
1982	3,245,967	174,970[n]	2,344,250	1.9	768,571	153,507	815,864	5.4	21.4	2.20[n]	1.40	5.6	30⅛-19⅝	11.3

a Excludes extraordinary net gain from tax benefit associated with operating loss carry-forward of $14.4 million ($0.59 per share). b Net loss; includes income, before taxes, from litigation settlement of $1.2 million and net charge for reserve for Dalkon Shield claims of $489.1 million ($19.53 per share). c Deficit. d Includes income, before taxes, from litigation settlement of $2.3 million. e Includes income, before taxes, from litigation settlement of $3.1 million. f From continuing operations; excludes net gain on sale of discontinued home products business of $11.6 million ($0.22 per share). g Excludes net gain on sale of Industrial Business Group of $3.3 million ($0.04 per share). h From continuing operations; excludes net income of discontinued Industrial Business Group of $3.5 million ($0.04 per share). i Excludes extraordinary net gain on early extinguishment of debt of $27.0 million ($0.52 per share) and net loss on disposal of Latin American operations of $27.6 million ($0.53 per share). j From continuing operations; excludes net loss from divested Hilton-Davis chemical business of $43.6 million ($0.73 per share). k From continuing operations; excludes net loss on operations of divested environmental control business of $1.5 million ($0.02 per share). l From continuing operations; excludes net loss from operations and sale of polymer chemical business of $238,000. m Excludes nonrecurring net charge for write-down and divestiture of assets and restructuring program of $553.3 million ($7.10 per share). n Includes nonrecurring net credit of $12 million ($0.15 per share).

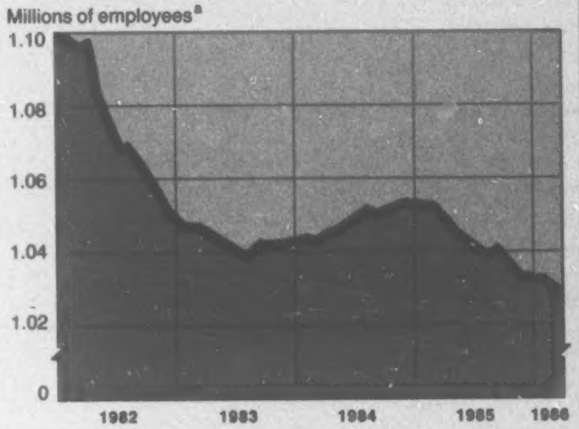
Chemical work force drops steeply in 1985

In 1985, the number of workers employed by the U.S. chemical industry fell to about 1,042,000, the lowest level of employment since 1975. A steady decline throughout 1985 and in the early months of 1986 wiped out the modest recovery that occurred in 1984. Employment also dropped again in the petroleum industry last year, but rubber manufacturers continued a trend toward higher numbers of workers.

Despite the overall downturn, two chemical sectors—soaps, cleaners, and toilet goods and paints and allied products—added a modest number of employees in 1985. Employment held steady in the industrial inorganic and organic chemicals segments. However, producers of plastics, synthetics, drugs, and agricultural chemicals trimmed their work forces.

Major chemical companies, as a group, added employees in 1985. Notable among the giant firms were Dow Chemical, which increased employment last year after several years of cuts, and Union Carbide, which cut back sharply on the number of its workers.

Chemical employment has declined steadily since the end of 1984



a Seasonally adjusted employment in U.S. chemicals and allied products industry; March and April 1986 figures are preliminary. **Source:** Department of Labor

INDUSTRIAL EMPLOYMENT: Stagnant at best throughout chemical industry

	All employees[a] (thousands)				Production workers[a] (thousands)				Workweek[a,b] (hours)			
	1985	1984	1983	1975	1985	1984	1983	1975	1985	1984	1983	1975
All manufacturing	19,426	19,412	18,434	18,323	13,214	13,310	12,530	13,043	40.5	40.7	40.1	39.5
Chemicals and allied products	1,042	1,048	1,043	1,015	576	582	579	580	41.9	41.9	41.6	41.0
Industrial inorganic chemicals	143	143	151	149	72	72	77	90	41.7	42.1	41.5	41.4
Plastic materials and synthetics	168	177	176	218	112	117	115	136	42.3	42.2	42.0	40.6
Drugs	205	206	201	167	94	96	98	84	41.0	40.7	41.0	41.0
Soap, cleaners, and toilet goods	148	145	142	122	94	93	89	73	41.0	41.3	41.1	40.6
Paints and allied products	63	62	60	62	30	30	29	33	41.4	41.7	41.0	40.5
Industrial organic chemicals	164	164	163	150	84	83	84	74	43.3	43.0	42.5	41.3
Agricultural chemicals	60	61	60	65	37	38	36	42	42.7	42.8	42.1	42.5
Miscellaneous chemical products	92	92	89	82	53	53	50	47	41.8	41.8	41.3	40.4
Petroleum and coal products	177	189	196	194	108	111	118	123	43.0	43.7	43.9	41.2
Rubber and miscellaneous plastics products	795	782	711	608	615	609	551	465	41.1	41.7	41.2	39.9

a Domestic employment. b Workweek of production or nonsupervisory workers. **Source:** Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Down slightly for chemical producers

Thousands[a]	1985[b]	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Total, all industry	570.3	544.5	522.1	509.8	487.8	450.6	423.9	404.4	382.8	364.4	363.3
Chemicals and allied products	66.9	67.1	66.0	61.6	54.7	51.4	50.0	48.3	46.4	44.4	45.2
Industrial chemicals	25.1	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6	20.1	21.1
Drugs and medicines	30.9[c]	30.1[c]	28.2	25.6	23.3	21.6	20.8	19.5	17.8	16.6	15.6
Other chemicals	10.9	10.3	10.6	10.1	9.8	8.9	7.8	7.5	8.0	7.8	8.5
Petroleum refining	13.4	13.2	14.7	15.6	13.0	10.8	10.1	9.9	8.9	8.6	8.4
Rubber products	na	na	na	8.1	10.3	na	8.1	7.9	9.1	8.6	8.4

a Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. b Preliminary. c Partly estimated. na = not available separately, but included in total. **Source:** National Science Foundation

CHEMICAL EMPLOYMENT: Modest growth last year, but sales per employee declines

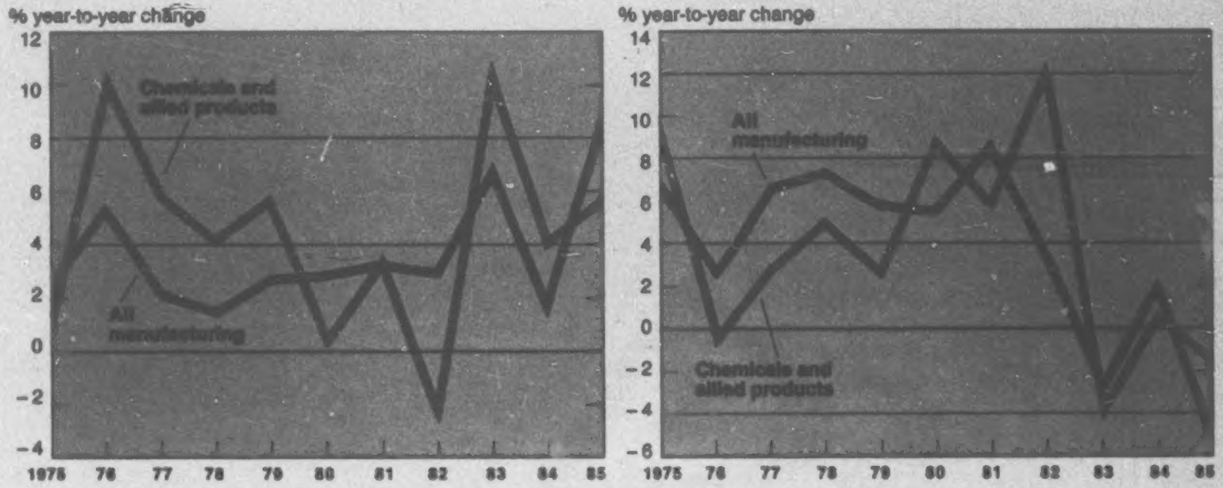
Thousands	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Air Products	18.7	17.7	16.7	18.9	16.2	15.8	14.6	14.3	13.7	13.4
American Cyanamid	36.4	38.2	38.7	40.2	41.8	42.6	44.2	44.0	43.8	39.4
Celanese	18.5	21.5	23.3	25.3	29.5	30.8	31.5	31.8	30.9	30.8
Crompton & Knowles	2.3	2.3	2.4	2.3	2.5	2.8	3.0	3.2	3.1	3.0
Dow Chemical	53.2	49.8	54.5	56.6	63.8	56.8	55.9	53.5	53.2	53.0
Ethyl	10.5	11.0	13.0	14.0	14.5	15.0	16.0	16.5	16.0	16.0
Freeport-McMoRan	4.5	4.6	4.8	5.0	5.2	2.7	3.9	3.5	3.7	3.8
H. B. Fuller	4.4	4.3	4.1	4.0	3.3	3.4	3.4	3.3	3.0	2.8
W. R. Grace	116.9	102.6	95.5	82.2	89.0	92.0	82.8	69.1	69.1	64.0
Hercules	25.4	26.3	24.2	24.5	25.9	26.1	27.4	27.1	26.3	25.7
International Flavors	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.5	3.3	3.1
International Minerals	8.7	9.0	8.4	8.4	10.6	10.6	10.3	9.9	9.9	9.7
Lubrizol	5.2	4.2	4.2	4.3	4.2	4.2	3.9	3.8	3.6	3.6
Monsanto	56.1	50.8	48.8	52.2	57.4	61.8	63.9	62.9	61.5	61.9
Nalco Chemical	5.1	4.8	4.6	4.6	4.7	4.3	4.1	4.1	4.2	3.8
Olin	14.9	17.8	18.2	17.5	20.3	21.0	21.7	22.7	22.4	22.0
Pennwalt	9.9	9.8	9.8	9.5	10.7	12.8	13.3	14.0	13.9	13.9
PPG Industries	37.5	37.7	37.0	37.0	36.6	37.3	38.2	37.4	36.6	36.3
Reichhold Chemicals	4.6	4.2	4.4	4.5	5.6	5.6	6.4	6.5	6.5	5.8
Rohm & Haas	11.8	11.9	11.4	11.5	13.5	13.2	13.3	13.1	13.0	13.3
Stepan	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.8	0.8	0.7
Union Carbide	91.5	98.4	99.5	103.2	110.3	116.1	115.8	113.4	113.7	113.1
TOTAL EMPLOYEES	**540.7**	**531.7**	**528.1**	**530.2**	**570.1**	**579.3**	**578.1**	**558.4**	**552.2**	**539.1**
ANNUAL CHANGE	**1.7%**	**0.7%**	**−0.4%**	**−7.0%**	**−1.6%**	**0.2%**	**3.5%**	**1.1%**	**2.4%**	**−1.1%**
SALES PER EMPLOYEE ($ thousands, current)	**$115.5**	**$117.5**	**$111.6**	**$108.6**	**$110.7**	**$103.3**	**$94.2**	**$81.0**	**$74.2**	**$69.0**
SALES PER EMPLOYEE ($ thousands, constant 1972[a])	**$39.7**	**$40.7**	**$39.7**	**$38.7**	**$40.1**	**$41.3**	**$44.2**	**$42.4**	**$40.1**	**$38.4**

a Based on producer price index for chemicals and allied products. **Note:** Data are not restated for acquisitions, divestitures, and similar changes. Data for 1985 do not account for work-force reductions that took effect during first-quarter 1986.

WAGES: Organic chemical workers continue to earn highest wages in chemical industry

	Hourly earnings[a]				Weekly earnings[a]			
	1985	1984	1983	1975	1985	1984	1983	1975
All manufacturing	$ 9.52	$ 9.18	$ 8.83	$4.83	$385.56	$373.63	$354.08	$190.79
Chemicals and allied products	11.57	11.08	10.58	5.39	484.78	464.25	440.13	220.99
Industrial inorganic chemicals	12.82	12.30	11.66	5.73	534.59	517.83	483.89	237.22
Plastic materials and synthetics	11.72	11.10	10.55	5.28	495.76	468.42	443.10	214.37
Drugs	10.75	10.23	9.72	5.18	440.75	416.36	398.52	212.38
Soap, cleaners, and toilet goods	10.26	9.89	9.65	5.15	420.66	408.46	396.62	209.09
Paints and allied products	10.07	9.75	9.34	5.01	416.90	406.58	382.94	202.91
Industrial organic chemicals	13.99	13.43	12.73	6.25	605.77	577.49	541.03	258.13
Agricultural chemicals	11.02	10.73	10.24	4.93	470.55	459.24	431.10	209.53
Miscellaneous chemical products	10.60	10.08	9.63	5.11	433.08	421.34	397.72	206.44
Petroleum and coal products	14.04	13.43	13.28	6.48	603.72	586.89	582.99	266.98
Rubber and miscellaneous plastic products	8.53	8.29	8.00	4.39	350.58	345.69	329.60	175.16

a For production and nonsupervisory workers in domestic employment. **Source:** Department of Labor



Chemical productivity rebounded in 1985 . . . **. . . thus unit labor costs fell slightly**

Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit output, calculated by dividing indexes for wages by indexes for output per workhour. Sources: Department of Labor, Federal Reserve Board, C&EN calculations

Productivity in the U.S. chemical industry improved in 1985, but most of the increase came as a result of falling employment rather than from increased production. And in spite of the improvement, productivity gains for manufacturers of chemicals and allied products lagged those for all manufacturing industries.

In 1985, production of chemicals increased 3.4% but work hours in the chemical industry declined 2.4%. As a result, productivity increased 5.9%, compared with a 4.0% increase in 1984.

At the same time, chemical producers were holding labor costs in check. Hourly production wages in 1985 increased just 4.3% over the year before. Consequently, unit labor costs fell to their lowest level since 1981. Unit labor costs in 1985 were down 1.5%, compared with a 0.7% rise in 1984 over the previous year.

However, for all manufacturing, improvements in the productivity scene was even better. For all manufacturing, productivity had increased 9.2% on a 6.7% rise in production and a 2.2% fall in workhours. In 1984, productivity for all manufacturing was up only 1.5% from the year before.

Like productivity, unit labor costs for all manufacturing outperformed chemicals, falling 5.4% from the year before on a 3.3% rise in hourly production wages. In 1984, unit labor costs for all manufacturing were up 2.3%.

PRODUCTIVITY: Improvement last year as output rises despite a decline in workhours

Indexes, 1977 = 100	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
CHEMICALS & ALLIED PRODUCTS											
Production	127.1	122.9	115.7	105.6	116.0	111.1	113.3	106.3	100.0	92.0	79.3
Workhours	93.7	96.0	93.9	95.2	101.7	101.0	103.1	102.2	100.0	97.3	92.6
Productivity	135.6	128.0	123.1	110.9	114.1	110.0	109.9	104.0	100.0	94.6	85.6
Hourly production wages	180.2	172.7	164.8	155.0	141.8	129.2	118.2	109.2	100.0	91.9	83.8
Unit labor costs	132.9	134.9	133.9	139.7	124.4	117.5	107.6	105.0	100.0	97.2	97.9
ALL MANUFACTURING											
Production	127.1	119.1	107.1	99.4	108.6	105.9	110.7	106.1	100.0	94.1	84.0
Workhours	93.9	96.0	87.7	87.0	97.9	98.9	106.2	104.5	100.0	96.1	90.4
Productivity	135.4	124.0	122.2	114.3	110.9	107.1	104.2	101.5	100.0	97.9	92.9
Hourly production wages	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6	100.0	91.9	85.0
Unit labor costs	123.2	130.2	127.3	130.9	126.8	116.6	113.2	107.0	100.0	93.8	91.5

Sources: Department of Labor, Federal Reserve Board, C&EN estimates

World chemical trade cools off

World chemical trade cooled off last year. After a 7.5% jump in 1984, world chemical exports slipped nearly 3% to an estimated $142.5 billion.

World trade numbers, however, have to be taken with a grain of salt. To determine a total world chemical export figure, it's necessary to go to several different sources, including the United Nations (always two years late with its data), the Organization for Economic Cooperation & Development (always one year late), the European Economic Community, and several individual countries. The big problem, of course, lies in the way these various organizations use exchange rates to convert foreign currencies into U.S. dollars.

Although currency conversion always is a problem, in the past few years, and especially last year, the problem was compounded because the exchange rate for U.S. dollars fluctuated wildly.

Nevertheless, it seems apparent that several major chemical exporters suffered setbacks last year. Chemical exports from EEC, for one thing, were down.

EEC exports to the U.S., however, increased a healthy 11% last year. The losses in chemical exports, then, had to come from developing country markets, just as was the case for exports by U.S. chemical producers.

U.S. chemical exports dipped 2% last year to $21.5 billion. Shipments held up adequately to such developed markets as Western Europe, Japan, and Canada. But important markets in developing areas, particularly Latin America and Asia, weakened considerably. Many countries in those regions cut back on imports to cope with their own domestic economic problems. Meanwhile, the expected improvement in U.S. chemical exports as a result of the weakening dollar had not yet taken hold.

U.S. TOTAL TRADE BALANCE:
Slips further into the red

$ Billions	1985	1984	1983	1975
Total exports	$213.1	$217.9	$200.5	$107.1
Total imports	345.3	325.7	258.0	96.1
Trade balance	−132.2	−107.8	−57.5	11.0

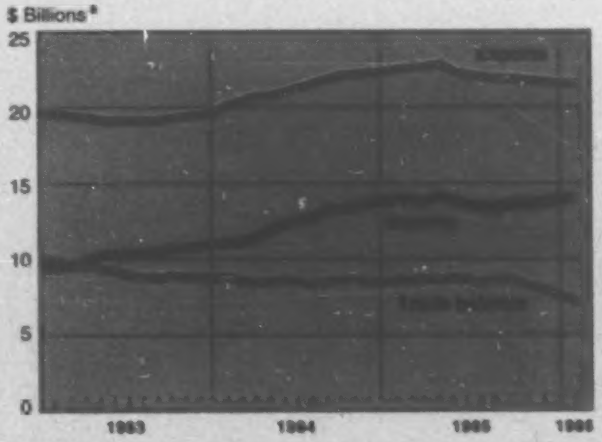
Source: Department of Commerce

U.S. CHEMICAL TRADE BALANCE:
The surplus continues to erode

$ Millions	1985	1984	1983	1975
Chemical exports	$21,759	$22,336	$19,751	$8705
Chemical imports	14,533	13,697	10,779	3696
Chemical trade balance	7,226	8,639	8,972	5009

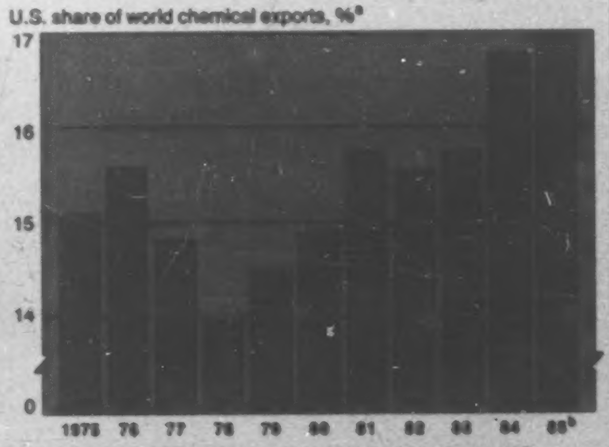
Source: Department of Commerce

Chemical trade balance shrinks further . . .



a Running 12-month totals. Source: Department of Commerce

. . . but U.S. share of world markets climbs



a U.S. chemical exports as a percentage of total world chemical exports less U.S. chemical imports. b C&EN estimate. Source: Department of Commerce

WORLD TRADE: Chemical business cools

$ Millions	1985	1984	1983	1975
CHEMICAL EXPORTS				
World	$142,500[a]	$146,421	$136,260	$61,212
U.S.	21,759	22,336	19,751	8,705
Canada	4,132	4,187	3,645	1,063
EEC, 10 countries	68,871	73,307	70,104	32,697
Belgium-Luxembourg	6,450	6,449	6,216	3,460
France	12,623	12,574	11,842	5,405
Italy	5,497	6,203	6,116	2,681
Netherlands	9,838	11,005	10,536	5,076
U.K.	9,106	11,014	10,491	4,826
West Germany	22,477	23,369	22,209	10,447
Switzerland	5,878	5,503	5,539	2,760
Japan	7,697	7,447	6,813	3,885
CHEMICAL IMPORTS				
U.S.	14,533	13,697	10,779	3,696
Canada	4,549	4,544	4,052	1,772
EEC, 10 countries	57,273	53,601	51,382	22,094
Belgium-Luxembourg	5,855	5,437	5,184	2,522
France	10,854	9,973	9,533	4,337
Italy	8,518	7,813	7,307	2,805
Netherlands	6,825	5,804	5,534	2,677
U.K.	7,425	8,470	7,764	3,123
West Germany	13,858	13,084	12,494	5,218
Switzerland	3,664	3,397	3,315	1,447
Japan	8,072	8,112	7,008	2,059

a C&EN estimate. Sources: United Nations, Organization for Economic Cooperation & Development, European Economic Community, individual country data

U.S. TRADE: More with Europe

$ Millions	1985	1984	1983	1975
U.S. CHEMICAL EXPORTS				
Canada	$ 2,698	$ 2,752	$ 2,546	$1223
Western Europe	6,742	6,497	5,892	2699
Eastern Europe	368	275	306	84
Communist Asia	513	645	353	5
Japan	2,908	2,961	2,607	589
Rest of Asia	3,024	3,292	2,859	990
Middle East	400	429	423	272
Latin America	3,681	3,827	3,273	2135
Australasia	704	842	696	248
Africa	456	510	492	271
Other	265	306	304	189
TOTAL	**$21,759**	**$22,336**	**$19,751**	**$8705**
U.S. CHEMICAL IMPORTS				
Canada	$ 2,913	$ 3,131	$ 2,390	$ 870
Western Europe	7,118	6,392	5,020	1708
Eastern Europe	380	325	197	23
Communist Asia	163	157	131	16
Japan	1,412	1,312	1,099	387
Rest of Asia	457	377	283	42
Middle East	218	124	113	40
Latin America	1,216	1,208	924	144
Australasia	231	251	234	240
Africa	203	196	227	24
Other	222	224	161	201
TOTAL	**$14,533**	**$13,697**	**$10,779**	**$3696**

Source: Department of Commerce

U.S. TRADE, BY PRODUCTS: Organic chemicals, plastics, and drugs lead advance in imports

	Chemical exports				Chemical imports			
$ Millions	1985	1984	1983	1975	1985	1984	1983	1975
Organic chemicals	$ 6,012	$ 6,093	$ 5,326	$2431	$ 4,576	$ 4,265	$ 3,477	$1042
Inorganic chemicals	1,967	2,184	1,838	943	1,984	2,064	1,615	835
Radioactive materials	1,311	1,421	1,213	314	1,417	1,394	952	196
Dyeing, tanning, and coloring materials	139	158	163	92	352	358	300	75
Pigments, paints, and varnishes	322	335	328	152	266	232	145	28
Medicinals and pharmaceuticals	2,708	2,628	2,494	866	1,084	931	703	235
Flavors, perfumes, cosmetics, toiletries	478	498	493	190	577	521	370	115
Cleaning and polishing materials	292	308	295	172	172	118	90	30
Ferilizer, manufactured	2,160	1,815	1,267	1083	967	1,142	997	626
Explosives and pyrotechnics	100	146	87	60	103	84	64	25
Plastics and resins	3,777	4,050	3,732	1173	1,631	1,484	1,098	227
Pesticides and disinfectants	614	707	630	a	399	308	251	a
Miscellaneous	1,878	1,992	1,885	1229	1,005	797	717	263
TOTAL	**$21,759**	**$22,336**	**$19,751**	**$8705**	**$14,533**	**$13,697**	**$10,779**	**$3696**

a Included in miscellaneous chemical products. Source: Department of Commerce

5 Foreign Chemical Industries—Western Europe

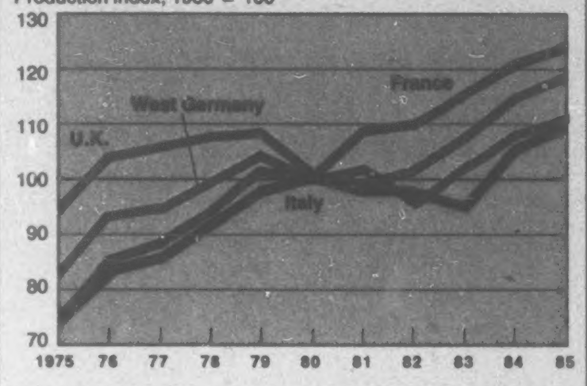
European chemical companies had another good year in 1985. West Germany's Bayer retained its position as top in total sales. BASF moved into the number two slot past Hoechst, which now stands at number three.

Profit margins improved for just about every company. Laporte Industries achieved a creditable 10%. Ciba-Geigy and Fisons earned about 8% on sales. Montedison experienced the biggest turnaround, netting a profit for the first time in a decade.

The changing value of the U.S. dollar is causing concern to European business executives. In 1985 as a whole, the dollar gained in strength against West European currencies. But about midyear a change set in, and the dollar began to weaken. The trend is continuing. As a result, European chemical producers face stiffer price competition from their U.S. counterparts.

Gains continue for chemical production

Production index, 1980 = 100



CHEMICAL INDUSTRY TRENDS: Output, prices generally higher as employment holds steady

$ Billions (U.S.)	1985	1984	1983	1982	1981
WEST GERMANY					
Sales	$ 50.5	$ 49.5	$ 49.7	$ 48.5	$ 51.6
Exports	26.1	25.1	24.0	22.9	23.8
Imports	15.0	14.0	13.6	13.0	13.3
Capital spending	2.4	2.2	2.7	2.8	3.1
Production index[a]	111.1	108.8	103.4	96.4	101.6
Price index[a]	121.6	118.1	113.9	113.7	108.7
Employees (thousands)	557	550	549	559	548
FRANCE[b]					
Sales	$ 32.3	$ 30.9	$ 30.1	$ 30.4	$ 33.4
Exports	12.8	12.2	11.5	11.2	11.9
Imports	10.0	9.2	8.9	9.1	9.2
Capital spending	1.2	1.1	1.0	1.1	1.2
Production index[a]	124.4	121.2	114.9	110.2	108.8
Price index[a]	160.0	153.1	139.9	128.2	114.2
Employees (thousands)	276	279	282	286	289
U.K.[b]					
Sales	$ 26.3	$ 25.2	$ 25.6	$ 28.2	$ 37.6
Exports	12.1	11.0	10.5	11.5	12.3
Imports	9.2	8.8	8.1	8.2	7.9
Capital spending	1.7	1.4	1.4	1.9	2.5
Production index[a]	119.4	114.9	108.7	100.8	98.7
Price index[a]	131.6	125.1	119.1	113.5	106.3
Employees (thousands)	326	329	330	338	395
ITALY					
Sales	$ 24.4	$ 23.6	$ 22.9	$ 22.7	$ 24.1
Exports	6.6	6.2	5.7	5.0	5.6
Imports	9.3	8.6	7.9	7.4	7.8
Capital spending	0.9	0.9	1.1	1.1	1.1
Production index[a]	110.0	106.2	100.0	98.3	98.1
Price index[a]	159.7	148.2	134.9	124.1	111.9
Employees (thousands)	233	241	251	260	271
SPAIN[b,c]					
Sales	$ 15.9	$ 15.2	$ 14.2	$ 15.2	$ 15.7
Exports	2.9	2.7	2.2	2.2	2.3
Imports	3.1	3.0	2.8	2.9	3.1
Capital spending	0.3	0.2	0.3	0.4	0.4
Production index[a]	113.9	111.0	104.5	100.0	98.3
Price index[a]	176.7	163.6	147.4	131.0	116.9
Employees (thousands)	240	241	242	243	244
BELGIUM[b,c,d]					
Sales	$ 14.1	$ 13.6	$ 13.2	$ 14.1	$ 15.3
Exports[d]	9.5	9.1	8.8	8.9	9.2
Imports[d]	6.9	6.6	6.3	6.3	6.4
Capital spending	0.4	0.4	0.4	0.3	0.4
Production index[a]	117.3	113.3	107.3	103.1	101.1
Price index[a]	145.0	139.9	133.7	126.0	110.7
Employees (thousands)	90	89	88	88	88
NETHERLANDS					
Sales	$ 13.9	$ 13.6	$ 13.1	$ 12.5	$ 13.6
Exports	12.9	12.5	12.0	11.3	11.9
Imports	8.0	7.2	6.8	6.7	7.1
Capital spending	0.7	0.8	0.7	0.6	0.6
Production index[a]	124.0	122.0	111.0	100.0	97.7
Price index[a]	120.0	116.0	115.0	114.0	114.4
Employees (thousands)	89	89	88	90	91
SWITZERLAND[b]					
Sales	$ 6.7	$ 6.5	$ 6.7	$ 6.6	$ 6.7
Exports	5.7	5.4	5.5	5.4	5.4
Imports	3.6	3.4	3.3	3.3	3.3
Production index[a]	122.9	115.7	109.6	103.0	104.2
Price index[a]	113.8	109.1	106.4	106.8	104.9
Employees (thousands)	65	65	68	na	63
SWEDEN					
Sales	$ 4.2	$ 4.1	$ 3.9	$ 4.0	$ 4.1
Exports	1.9	1.8	1.8	1.6	1.6
Imports	2.7	2.5	2.7	2.6	2.5
Capital spending	0.3	0.3	0.3	0.3	0.3
Production index[a]	116.2	114.6	113.2	104.8	109.4
Price index[a]	155.5	147.0	135.5	120.4	108.8
Employees (thousands)	44	44	43	44	41
NORWAY					
Sales	$ 2.0	$ 2.1	$ 2.1	$ 2.0	$ 1.9
Exports	1.2	1.2	1.1	1.0	1.5
Imports	1.1	1.0	0.9	0.9	1.0
Capital spending	0.1	0.1	0.1	0.1	0.1
Production index[a]	120.0	121.0	110.9	100.6	101.7
Price index[a]	132.6	128.1	123.6	117.9	112.5
Employees (thousands)	16	16	17	18	17

a 1980 = 100. b Excludes fibers. c Includes rubber and plastics processing. d Includes Luxembourg for exports and imports. Sources: National agencies and European Council of Chemical Manufacturers' Federations (CEFIC)

MAN-MADE FIBERS: Production of noncellulosics expands but cellulosics stagnate

Millions of lb	1985		1984		1983		1982		1981		Change, 1984–85	
	Noncellulosics[a]	Cellulosics	Noncellulosics[b]	Cellulosics	Noncellulosics[b]	Cellulosics	Noncellulosics[b]	Cellulosics	Noncellulosics[b]	Cellulosics	Noncellulosics	Cellulosics
West Germany	1753	372	1696	359	1654	334	1511	315	1735	322	3%	4%
Italy	1454	68	1324[a]	68	1166[a]	65	1091[a]	102	1115[a]	133	10	0
Spain	633	80	578	73	539	70	507	95	526	111	10	10
U.K.	545[c]	208[d]	559[c]	305[d]	541[c]	330[d]	506[c]	263[d]	612[c]	298[d]	−3	−32
France	437	44	452	61	437	83	435	100	444	119	−3	−28
Benelux countries	364	95	206	94	189	90	198	124	229	144	77	1
Switzerland	226	0	218	0	204	0	183	0	197	0	4	—
Ireland	140	0	130	0	118	0	114	0	111	0	8	—
Portugal	129	1	106	2	95	1	99	3	83	7	22	−50
Austria	63	265	53	268	53	251	51	251	53	257	19	−1

a Includes polypropylene. b Excludes polypropylene. c Includes cellulose acetate filament. d Excludes cellulose acetate filament. Source: Comité International de la Rayonne et des Fibres Synthétiques

PRODUCTION: Nearly equally split between increases and decreases

Millions of lb	1985	1984	1983	1982	Change 1984–85
FRANCE					
Sulfuric acid	9433	9898	9024	8858	−5%
Hydrochloric acid	1446	1686	1483	1514	−14
Chlorine	3060	3103	2872	2759	−1
Sodium hydroxide	3196	3274	3064	2939	−2
Ammonia	4422	5170	4312	4180	−14
Benzene	1399	1343	1373	1133	4
Toluene	89	87	90	69	2
Xylenes	277	188	199	113	47
Ethylene	4749	4581	4563	4112	4
Propylene	2730	2652	2455	2277	3
Butadiene	634	667	620	569	−5
Formaldehyde	203	210	208	175	−3
Methanol	na	697	761	753	—
Polyethylene	2047	2045	2070	1938	0
Polypropylene	933	871	842	692	7
Polystyrene	1074	1060	1056	972	1
Polyvinyl chloride	1804	1737	1796	1729	4
Synthetic rubber	1199	1218	1125	1045	−2
Phosphate fertilizers (P_2O_5)	1340	1495	1577	2447	−10
ITALY					
Sulfuric acid	9596	9370	9071	8818	2%
Nitric acid	2575	2420	2261	2247	6
Phospheric acid	889	996	999	970	−12
Chlorine	2021	2095	1974	1701	−4
Sodium hydroxide	2257	2359	2219	1999	−4
Ammonia	3249	3233	2494	2804	0
Benzene	1078	1179	1160	841	−9
Toluene	766	688	658	580	11
Xylenes	919	871	804	594	6
Ethylene	na	2504	2337	1923	—
Propylene	na	1244	1143	961	—
Butadiene	na	399	380	345	—
Phthalic anhydride	na	213	298	298	—
Formaldehyde	303	325	312	275	−7
Acetic acid	132	140	237	342	−6
Carbon black	403	380	339	334	6
Polyethylene	1410	1602	1564	1167	−12
Polystyrene	708	695	725	674	2
Polyvinyl chloride	1357	1493	1391	1302	−9
Synthetic rubber	na	514	504	475	—
Nitrogen fertilizers (N)	7040	7134	6003	5738	−1

Millions of lb	1985	1984	1983	1982	Change 1984–85
U.K.					
Sulfuric acid	5556	5829	5692	5692	−5%
Hydrochloric acid[a]	337	345	286	260	−2
Phosphoric acid	826	896	981	897	−8
Chlorine	2269	2156	1980	1933	5
Benzene	1837	1660	1597	1253	11
Ethylene	3182	2913	2540	2454	9
Propylene	2141	2147	1719	1695	0
Butadiene	655	570	523	503	15
Acetone	323	355	268	298	−9
Formaldehyde	272	228	226	236	19
Phenol	259	406	315	308	−36
Polyethylene	999	893	896	937	12
Polypropylene	592	568	506	487	4
Polyvinyl chloride	389	379	420	387	3
Synthetic rubber	593	635	571	537	−7
WEST GERMANY					
Sulfuric acid	7371	8002	8009	8334	−8%
Hydrochloric acid	2079	2104	1980	1865	−1
Nitric acid	6361	6284	5778	5040	−1
Chlorine	7686	7536	6900	6253	2
Sodium hydroxide	7581	7408	6830	6318	2
Sodium carbonate	3096	3000	2679	2432	3
Sodium sulfate	306	281	275	472	9
Ammonia	5036	5163	4495	4145	−3
Benzene	2723[b]	2734[b]	2939	2256	0
Toluene	860	816	691	590	5
Xylenes	1089	1003	1127	1012	9
Ethylene	6661	7093	6980	5808	−6
Propylene	3665	3969	3793	3259	−8
Butadiene	1851	1661	1580	1275	11
Ethylene oxide	1073	1044	993	886	3
Ethylene glycol	504	509	450	404	−1
Propylene glycol	371	372	351	279	0
n-Butanol	604	589	562	508	3
Acetaldehyde	726	737	647	571	−1
Acetic acid	655	668	590	562	−2
Ethanol	170	120	171	220	42
Formaldehyde	1253	1283	1175	1070	−2
Methanol	1302	1504	1470	1559	−13
Phthalic anhydride	378	453	429	439	−17
Polyethylene	2725	2882	2996	2473	−5
Polyvinyl chloride	2658	2490	2398	1902	7
Synthetic rubber	1007	988	951	888	2
Nitrogen fertilizers (N)	1826	1843	1642	1464	−1
Phosphate fertilizers (P_2O_5)	394	473	552	595	−17

a Manufacturers' sales. b From petroleum refining only. Sources: Government agencies for each country

COMPANY RESULTS: Profitability up more often than not, as are capital and R&D outlays

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Bayer (West Germany)						
1985	$15,621.1	$488.4	3.1%	$700.0	$725.9	176.1
1984	15,098.9	411.9	2.7	646.3	686.3	174.8
1983	14,641.6	295.7	2.0	734.1	664.3	174.8
1982	14,335.0	26.3	0.2	846.6	637.9	179.4
BASF (West Germany)						
1985	$15,094.2	$339.5	2.2%	$950.3	$488.1	130.2
1984	14,175.4	314.0	2.2	719.6	435.8	115.8
1983	13,769.0	202.7	1.5	639.2	466.3	114.1
1982	13.368.7	113.2	0.8	824.3	483.1	115.9
Hoechst (West Germany)						
1985	$14,531.3	$499.3	3.4%	$804.4	$708.5	180.6
1984	14,546.3	474.4	3.3	724.9	637.9	177.9
1983	14,583.9	356.5	2.4	733.3	634.1	179.8
1982	14,397.5	130.5	0.9	850.6	642.4	182.2
Imperial Chemical Industries (U.K.)						
1985	$13,910.5	$716.0[a]	5.1%	$822.3	$452.7	118.6
1984	13,247.3	808.8[b]	6.1	589.6	399.7	115.6
1983	12,528.1	602.4[c]	4.8	547.8	418.8	117.9
1982	12,886.2	253.9	2.0	511.4	427.3	123.8
Ciba-Geigy (Switzerland)						
1985	$7,406.9	$598.4	8.1%	$493.1	$679.7	81.0
1984	7,435.7	505.1	6.8	428.5	619.6	81.4
1983	7,019.5	369.5	5.3	395.2	594.3	79.2
1982	6,802.0	306.4	4.5	427.6	578.8	79.4
Montedison (Italy)						
1985	$7,403.4	$127.3[d]	1.7%	$345.7	$157.2	69.7
1984	7,047.2	(14.8)[e,f]	—	279.5	142.3	71.2
1983	7,017.8	(207.4)[e,g]	—	295.6	171.2	72.8
1982	6,665.9	(529.9)[e,h]	—	324.5	170.7	84.2
DSM (Netherlands)						
1985	$7,267.8	$146.1[i]	2.0%	$297.3	$57.2	26.6
1984	7,018.8	179.6[j]	2.6	285.7	54.5	27.2
1983	6,929.8	80.2[k]	1.2	230.9	61.4	27.9
1982	6,806.1	(52.2)[e,l]	—	165.5	63.7	28.6
Rhône-Poulenc (France)						
1985	$6,240.5	$257.1	4.1%	$460.5	$317.6	78.0
1984	5,858.4	227.6	3.9	395.2	281.7	80.0
1983	5,658.4	12.9	0.2	365.4	286.0	80.8
1982	5,661.5	(128.5)[e]	—	329.7	267.6	81.8
Akzo (Netherlands)						
1985	$5,424.7	$275.1[m]	5.1%	$303.6	$218.4	65.0
1984	5,146.4	252.0[n]	4.9	244.2	198.8	66.1
1983	5,292.8	189.2[o]	3.6	219.3	217.5	66.3
1982	5,301.2	84.9[p]	1.6	273.4	323.2	73.7

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Norsk Hydro (Norway)						
1985	$4,874.8	$241.9	5.0%	$736.9	$44.4	26.4
1984	4,357.5	247.2	5.7	596.4	29.5	19.8
1983	4,077.9	147.7	3.6	593.0	29.0	18.8
1982	3,185.9	85.4	2.7	509.3	na	19.6
Solvay (Belgium)						
1985	$3,796.6	$187.6[q]	4.9%	$235.5	$131.8	44.5
1984	3,871.5	200.2[r]	5.2	179.9	126.7	43.5
1983	3,887.0	128.8[s]	3.3	155.3	127.1	44.2
1982	3,891.3	47.6[t]	1.2	153.8	131.1	45.4
Hoffmann-La Roche (Switzerland)						
1985	$3,632.3	$183.6	5.1%	$160.8	$486.3	45.5
1984	3,519.1	161.8	4.6	194.0	486.2	46.2
1983	3,576.2	156.4	4.4	216.1	473.5	45.9
1982	3,499.2	138.5	4.0	346.7	453.5	46.5
Sandoz (Switzerland)						
1985	$3,436.2	$215.0	6.3%	$169.9	$294.7	40.2
1984	3,163.4	174.9	5.5	129.4	269.8	38.0
1983	3,117.1	152.4	4.9	128.6	261.9	38.1
1982	2,981.8	134.5	4.5	124.6	244.8	37.3
BOC International (U.K.)						
1985	$2,465.5	$142.2[u]	5.8%	$313.2	$46.3	36.9
1984	2,811.5	106.0[v]	3.8	322.6	56.6	38.7
1983	2,582.1	83.2[w]	3.2	468.1	40.8	39.1
1982	2,686.9	113.0[x]	4.2	388.3	43.6	38.4
Fisons (U.K.)						
1985	$838.8	$73.4[y]	8.8%	$7.4	$22.7	9.0
1984	738.8	50.8[z]	6.9	9.4	20.1	8.6
1983	554.5	38.1[aa]	6.9	4.7	21.2	7.5
1982	613.8	25.4	4.1	3.2	29.4	7.5
Albright & Wilson (U.K.)						
1985	$833.2	$27.9[bb]	3.3%	$55.8	na	6.8
1984	761.2	29.3[cc]	3.8	46.8	na	6.3
1983	865.3	31.9[dd]	3.7	37.2	na	6.3
1982	929.6	12.4[ee]	1.3	33.6	na	7.2
UCB Belgium						
1985	$524.3	$16.0[ff]	3.0%	$22.9	$19.5	6.4
1984	534.8	22.9[gg]	4.3	21.6	18.4	6.5
1983	572.4	22.0[hh]	3.8	23.5	17.6	6.4
1982	606.6	9.4	1.6	20.0	17.2	6.7
Laporte Industries (U.K.)						
1985	$463.9	$46.3[ii]	10.0%	$35.0	na	3.6
1984	475.4	37.3	7.8	13.5	na	3.6
1983	440.4	27.7[jj]	6.3	7.7	na	3.5
1982	425.5	19.3[kk]	4.6	21.7	na	3.5

a Excludes nonrecurring loss of $51.9 million. b Excludes nonrecurring loss of $26.7 million. c Excludes nonrecurring loss of $28.8 million. d Excludes nonrecurring minority interests' loss of $68.1 million. e Deficit. f Excludes nonrecurring gain of $17.6 million and minority interests' loss of $50.1 million. g Excludes nonrecurring minority interests' loss of $4.6 million. h Excludes nonrecurring loss of $105.7 million and minority interests' profit of $0.7 million. i Excludes nonrecurring loss of $13.0 million and minority interests' loss of $12.0 million. j Excludes nonrecurring loss of $17.6 million and minority interests' loss of $17.5 million. k Excludes nonrecurring gain of $6.3 million and minority interests' loss of $29.1 million. l Excludes minority interests' loss of $18.1 million. m Excludes extraordinary gain of $0.6 million and minority interests' loss of $22.0 million. n Excludes nonrecurring loss of $10.6 million and minority interests' loss of $6.7 million. o Excludes nonrecurring loss of $36.0 million and minority interests' loss of $3.0 million. p Excludes nonrecurring loss of $18.4 million and minority interests' loss of $4.8 million. q Excludes nonrecurring loss of $50.5 million. r Excludes nonrecurring loss of $60.9 million. s Excludes nonrecurring loss of $25.7 million. t Excludes nonrecurring gain of $9.2 million. u Excludes nonrecurring loss of $9.2 million. v Excludes extraordinary gain of $16.7 million. w Excludes nonrecurring loss of $19.4 million. x Excludes nonrecurring gain of $10.7 million. y Excludes nonrecurring loss of $4.8 million. z Excludes nonrecurring loss of $5.6 million. aa Excludes nonrecurring loss of $10.0 million. bb Excludes nonrecurring loss of $3.7 million. cc Excludes nonrecurring loss of $0.3 million. dd Excludes nonrecurring loss of $1.5 million. ee Excludes nonrecurring loss of $17.2 million. ff Excludes extraordinary gain of $7.2 million. gg Excludes extraordinary gain of $0.7 million. hh Excludes nonrecurring loss of $3.0 million. ii Excludes extraordinary gain of $4.2 million. jj Excludes nonrecurring loss of $3.5 million. kk Excludes nonrecurring gain of $138.4 million. na = not available.

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	$1.00 (U.S.) is equivalent to:									
	Belgium	France	Italy	Netherlands	Norway	Spain	Sweden	Switzerland	U.K.	West Germany
1985	59.38 francs	8.99 francs	1909 lire	3.32 guilders	8.60 crowns	170.04 pesetas	8.60 crowns	2.46 francs	0.771 pound	2.94 marks
1984	57.78 francs	8.74 francs	1757 lire	3.21 guilders	8.16 crowns	160.76 pesetas	8.27 crowns	2.35 francs	0.748 pound	2.85 marks
1983	51.13 francs	7.62 francs	1519 lire	2.85 guilders	7.30 crowns	143.43 pesetas	7.67 crowns	2.10 francs	0.659 pound	2.55 marks
1982	45.69 francs	6.57 francs	1353 lire	2.67 guilders	6.45 crowns	109.86 pesetas	6.28 crowns	2.03 francs	0.571 pound	2.43 marks
1981	37.13 francs	5.44 francs	1137 lire	2.50 guilders	5.74 crowns	92.31 pesetas	5.06 crowns	1.96 francs	0.493 pound	2.26 marks

Source: International Monetary Fund

Foreign Chemical Industries—Japan

5

Japanese chemical companies, like many of their counterparts throughout the world, are cutting back on basic petrochemical operations and seeking profitable niches in upgraded, higher-value products.

Production growth was lower in the chemical industry in 1985 than for all manufacturing industries as a whole. Output of petrochemicals and plastics, for instance, grew an anemic 0.4% and 0.2%, respectively, last year.

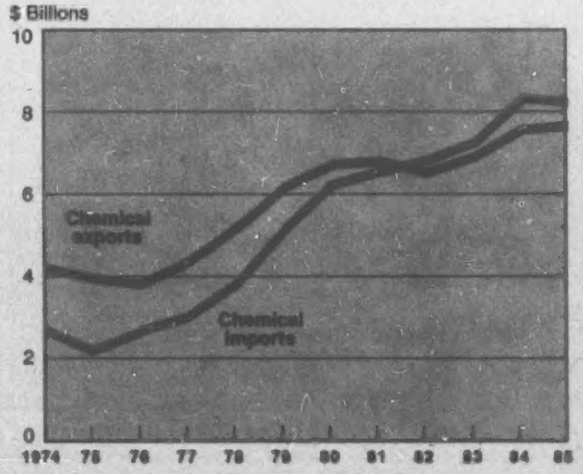
On the financial side, the more diversified companies, which depend less on basic petrochemicals, generally fared best. Profit margins, as a rule, were higher for them as profits in Japan's petrochemical industry deteriorated last year.

PRODUCTION: Growth lags for chemicals

Production index, 1980 = 100	1985	1984	1983	1982	Change 1984–85
All manufacturing	122.1	116.7	104.9	101.4	5%
All chemicals	121.8	117.9	108.8	102.5	3
Inorganic chemicals and pigments	110.3	105.9	101.7	95.7	4
Alkalies and chlorine	95.9	95.2	90.7	90.1	1
Organic chemicals	95.6	96.9	86.6	86.5	−1
Petrochemicals	114.1	113.7	98.5	92.4	0
Aromatics	112.0	106.6	96.1	90.7	5
Cyclic intermediates and dyes	117.0	116.9	105.1	97.5	0
Plastics	119.9	119.7	105.2	96.5	0
Synthetic fibers	100.6	100.2	97.1	96.0	0
Synthetic rubber	105.8	106.1	91.6	85.1	−0
Fertilizer	76.8	79.8	77.4	80.2	−3
Textile materials	115.0	108.0	96.6	97.0	6
Medicinals and drugs	143.0	135.0	126.9	116.8	6

Source: Ministry of International Trade & Industry

Chemical trade remains in the red



Source: Ministry of International Trade & Industry

PRODUCTION: Sprinkled with minus signs

Thousands of metric tons unless otherwise indicated	1985	1984	1983	1982	Change 1984–85
INORGANIC CHEMICALS					
Ammonia	1981	2029	1881	2010	−2%
Ammonium chloride	373	387	435	486	−4
Ammonium sulfate	1837	1829	1722	1689	0
Calcium carbide	441	478	476	483	−8
Calcium superphosphate	529	559	559	527	−5
Carbon black	632	606	568	504	4
Chlorine, liquid	926	897	818	794	3
Hydrochloric acid	549	521	511	551	5
Nitrogen, millions of cu m	6220	5896	5369	5236	5
Oxygen, millions of cu m	7388	7216	6434	6493	2
Sodium carbonate	1057	1036	1103	1162	2
Sodium hydroxide	3075	3085	2863	2792	0
Sodium silicate	594	596	588	650	0
Sulfuric acid	6580	6458	6662	6530	2
Titanium dioxide	217	205	196	184	6
ORGANIC CHEMICALS					
Acetaldehyde	271	297	255	279	−9
Acetic acid	344	350	328	353	−2
Acetone	237	246	247	229	−4
Acrylonitrile	541	523	459	489	3
Benzene[a]	2084	2013	1750	1888	4
Butadiene	639	627	556	522	2
Butanol	258	243	229	228	6
Caprolactam	455	436	395	388	4
Cyclohexane	524	492	454	426	7
Dioctyl phthalate	241	249	231	221	−3
Ethylene	4224	4390	3688	3950	−4
Ethylene dichloride	1901	1939	1736	1548	−2
Ethylene glycol	440	429	357	385	3
Ethylene oxide	554	533	468	471	4
Methanol	254	280	373	625	−9
Octanol	230	246	219	226	−7
Phenol	262	272	271	211	−4
Phthalic anhydride[a]	162	156	161	159	4
Propylene	2980	2981	2658	2565	0
Propylene glycol	219	205	194	185	7
Styrene	1418	1423	1167	1086	0
Terephthalic acid	854	742	702	649	15
Toluene	803	784	831	803	2
Toluene diisocyanate	84	76	74	67	11
Urea	929	1120	980	1187	−17
Xylene	1523	1401	1264	1225	9
PLASTICS					
Phenolic resins	325	334	325	281	−3
Polyethylene	2027	2251	2027	1674	−10
Polypropylene	1304	1271	1304	941	3
Polystyrene	1599	1503	1599	1190	6
Polyvinyl chloride	1550	1504	1550	1218	3
SYNTHETIC RUBBER	1158	1160	1158	931	0

a Petroleum-based product only. Source: Ministry of International Trade & Industry

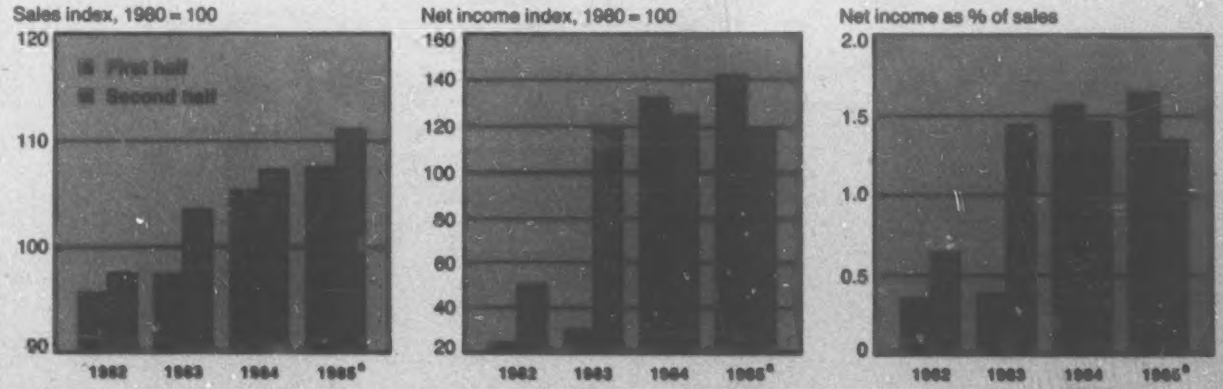
COMPANY RESULTS: Generally little change in profitability or employment last year

$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Mitsubishi Chemical Industries[a]					
1985	$3963	$33.1	0.8%	$4016	8.2
1984	3271	7.0	0.2	3211	8.3
1983	3155	0.6	0.0	3479	8.5
1982	3142	(36.5)[b]	—	3326	8.4
Sumitomo Chemical[c]					
1985	$3219	$38.9	1.2%	$3277	7.1
1984	2876	58.4	2.0	2818	6.9
1983	2783	17.3	0.6	2775	7.9
1982	2681	(30.6)[b]	—	2510	9.1
Asahi Chemical Industry[d]					
1985	$3910	$73.3	1.9%	$3661	15.9
1984	3129	57.3	1.8	3027	15.9
1983	2985	47.0	1.6	3022	16.3
1982	2670	45.8	1.7	2809	14.0
Toray Industries[d]					
1985	$3177	$78.2	2.5%	$3326	12.6
1984	2563	61.4	2.4	2663	13.2
1983	2588	66.0	2.6	2576	14.1
1982	2398	59.4	2.5	2385	13.9
Mitsui Toatsu Chemicals[d]					
1985	$2102	$14.7	0.7%	$2242	5.4
1984	1672	8.6	0.5	1810	5.3
1983	1695	(14.7)[b]	—	1794	5.4
1982	1783	44.9	2.5	1790	5.7

$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Teijin[d]					
1985	$2102	$70.9	3.4%	$2210	7.0
1984	1766	57.3	3.2	1842	7.2
1983	1797	51.4	2.9	1846	7.1
1982	1751	30.1	1.7	1953	7.1
Showa Denko[c]					
1985	$2066	$20.1	1.0%	$2738	4.6
1984	1683	0.5	0.0	2069	4.6
1983	1500	(6.6)[b]	—	2086	5.0
1982	1539	(2.9)[b]	—	2004	5.3
Mitsubishi Petrochemical[c]					
1985	$2139	$22.4	1.1%	$1939	2.4
1984	1592	43.3	2.7	1553	2.3
1983	1547	2.0	0.1	1644	2.5
1982	1508	(37.4)[b]	—	1767	3.5
Dainippon Ink & Chemicals[d]					
1985	$2102	$26.4	1.3%	$1722	6.2
1984	1642	20.1	1.2	1449	6.0
1983	1681	19.0	1.1	1472	6.0
1982	1609	17.9	1.1	1426	5.9
Sekisui Chemical[d]					
1985	$1769	$22.5	1.3%	$1439	6.2
1984	1415	16.9	1.2	1184	6.1
1983	1369	15.7	1.2	1199	6.1
1982	1294	9.0	0.7	1238	6.2

a Fiscal year ends Jan. 31. b Deficit. c Fiscal year ends Dec. 31. d Fiscal year ends March 31; 1985 data for these companies are based on actual results for the first half of the year and estimates for the second half. **Note:** Monetary statistics are converted from yen to U.S. dollars on the basis of $1.00 equals, 1985, 204.6 Y; 1984, 244.6 Y; 1983, 236.7 Y; 1982, 235.8 Y. Year-to-year changes in sales, net income, and assets are affected by these fluctuations in the currency exchange rate. **Source:** Toyo Keizai Shinposha

Chemical firms' profits hit a snag in 1985's second half



a Data for second half of 1985 are estimated. **Note:** Based on results of 10 leading Japanese chemical companies: Mitsubishi Chemical Industries, Sumitomo Chemical, Asahi Chemical Industry, Toray Industries, Mitsui Toatsu Chemicals, Teijin, Showa Denko, Mitsubishi Petrochemical, Dainippon Ink & Chemicals, and Sekisui Chemical. For most, but not all, of these companies, the fiscal year ends March 31. **Source:** Toyo Keizai Shinposha

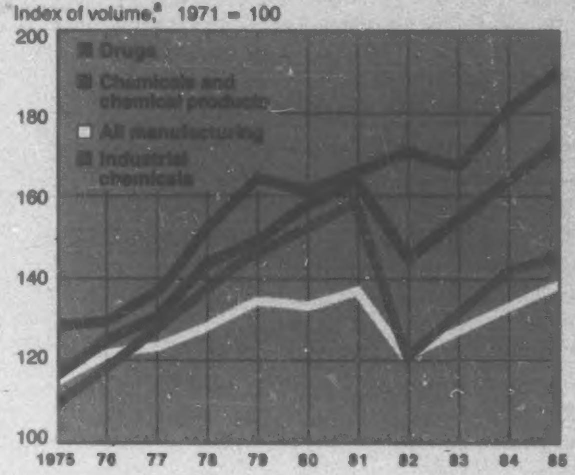
Supported by a full year of output from some new world-scale plants, ethylene—and some of its derivatives—led the chemical pack in production gains last year. Weaknesses, however, showed up in some fertilizer products and in pulp and paper chemicals.

Weak selling prices continued to weigh on several basic chemicals. Prices of all commodities rose 3% last year, but chemical prices increased less than half as much. Prices of organic chemicals were down 6%, and olefin prices alone slumped 12%.

This price pressure made profits tough to come by. But oil and gas are likely to be less expensive this year. And Canada's dollar remains weak against the U.S. dollar. This will make Canadian chemicals very competitive in the U.S.

Note on currency conversion: Monetary statistics in this section have been converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. equals, 1985, $0.734 Canadian; 1984, $0.765 Canadian; 1983, $0.804 Canadian; 1982, $0.814 Canadian; 1981, $0.843 Canadian.

Output climbs, with drugs setting pace



a Gross domestic product. **Source:** Statistics Canada

COMPANY RESULTS: Profits remain low

$ Millions (U.S.)	Sales	Net income[a]	Profit margin	Capital expenditures	Employees (thousands)
C-I-L Inc.					
1985	$927.8	$28.6	3.1%	$86.6	6.3
1984	899.6	29.1	3.2	90.5	6.3
1983	895.5	19.2	2.1	87.6	6.7
1982	862.7	12.4	1.4	69.6	6.9
Celanese Canada					
1985	$272.8	$ 9.3	3.4%	$11.7	2.1
1984	296.4	6.0	2.0	10.2	2.8
1983	304.6	7.6	2.5	9.7	3.4
1982	248.7	(4.2)[b]	—	44.0	3.4
Du Pont Canada					
1985	$870.7	$15.1	1.7%	$52.4	4.9
1984	895.5	31.5	3.5	34.6	5.0
1983	897.6	28.3	3.2	20.3	5.0
1982	797.7	(6.0)[b]	—	20.5	5.4
Polysar					
1985[c]	$1371.1	$ 0.1	—	$ 40.1	6.7
1984	1083.4	27.5	2.5%	43.6	6.0
1983	1074.9	7.0	0.7	155.9	6.0
1982	1081.6	(24.8)[b]	—	168.5	6.6
Union Carbide Canada					
1985[d]	$368.0	$ 0.2	0.1%	$21.4	3.8
1984	528.9	4.4	0.8	19.3	4.1
1983	552.4	(1.1)[b]	—	43.5	4.2
1982	562.7	(14.6)[b]	—	55.0[e]	4.5

a Excludes extraordinary gains and losses. b Deficit. c Acquired interest in Petrosar formerly held by Du Pont Canada and Union Carbide Canada. d Reflects divestment of polyethylene business. e Excludes $41.4 million (U.S.) addition to Prentiss, Alta., ethylene glycol plant transferred to another Union Carbide subsidiary.

PRODUCTION: Farm chemicals do poorly

Thousands of metric tons	1985	1984	1983	1982	Change 1984–85
INORGANIC CHEMICALS					
Ammonia	3620	3493	2888	2509	4%
Ammonium nitrate	1054	1035	934	1018	2
Ammonium phosphate	1301	1383	1259	888	−6
Chlorine	1424	1424	1385	1233	0
Hydrochloric acid	158	161	170	135	−2
Nitric acid	1128	1100	1061	977	3
Phosphoric acid, 100% P_2O_5	627	691	656	503	−9
Sodium chlorate	336	313	294	264	7
Sodium hydroxide	1589	1574	1528	1367	1
Sulfuric acid	3890	4043	3686	3131	−4
ORGANIC CHEMICALS					
Acetone	23	25	25	23	−8
Benzene	688	549	580	504	25
Butadiene	132	127	133	118	4
Ethylene	1744	1464	1196	1013	19
Formaldehyde	na	97	90	70	na
Methanol	na	1872	1671	na	na
Propylene	648	656	715	618	−1
Toluene	473	395	411	470	20
Urea	2033	2162	1445	1231	−6
Xylenes	415	406	426	431	2
PLASTICS					
Polyesters, unsaturated	36	34	26	27	7
Polyethylene, high density	229	227	211	194	1
Polyethylene, low density	733	529	412	376	39
Polystyrene[a]	178	171	na	126	4
Polyvinyl chloride	280[b]	252	243	194	11

a Includes acrylonitrile-butadiene-styrene resins in 1984 and 1985. b C&EN estimate. na = not available. Source: Statistics Canada

SHIPMENTS: A weak year for industrial chemicals

$ Millions (U.S.)	1985	1984	1983	1982	1981	Change 1984–85
All manufacturing	$179,177	$174,373	$163,192	$152,551	$160,747	3%
Chemicals and chemical products	12,898	12,821	12,613	11,573	11,118	1
Industrial chemicals, inorganic	2,639	2,683	2,556	2,343	1,848	−2
Industrial chemicals, organic	2,833	2,966	3,102	2,947	2,699	−4
Plastics and synthetic resins	1,317	1,331	1,302	1,126	1,275	−1
Pharmaceuticals and medicinals	1,536	1,468	1,336	1,187	1,119	5
Adhesives	98	94	92	64	na	4
Paint and varnish	881	815	784	667	742	8
Soaps and cleansers	1,028	962	940	902	860	7
Toilet preparations	626	614	597	542	497	2
Agricultural chemicals	291	272	267	158	na	7
Printing ink	184	183	172	149	179	1
Miscellaneous	1,292	1,258	1,274	1,317	1,526	3
Synthetic fibers	563	568	607	485	na	−1

na = not available. Source: Statistics Canada

CHEMICAL IMPORTS: Nearly unchanged

$ Millions (U.S.)	1985	1984	1983	Change 1984–85
Inorganic chemicals	$ 374	$ 381	$ 330	−2%
Organic chemicals	1107	1120	1019	−1
Fertilizers and fertilizer materials	152	158	148	−4
Synthetic and reclaimed rubber	160	158	129	1
Plastic materials	651	644	604	1
Plastic film and sheet	278	253	215	10
Other plastic shapes and forms	214	202	146	6
Dyes, except dyeing intermediates	49	56	62	−12
Pigments, lakes, and toners	78	77	65	1
Paints and related products	127	113	89	12
Other chemical products	807	824	724	−2
TOTAL	**$3997**	**$3986**	**$3531**	**0%**
Imports from U.S.	**$3034**	**$3114**	**$2754**	**−3%**
U.S. share, %	**75%**	**78%**	**78%**	

Source: Statistics Canada

CHEMICAL EXPORTS: Slightly lower

$ Millions (U.S.)	1985	1984	1983	Change 1984–85
Chemical elements	$ 158	$ 174	$ 150	−9%
Other inorganic chemicals	828	797	631	4
Organic chemicals	995	992	966	0
Fertilizers and fertilizer materials	946	1171	933	−19
Synthetic rubber and plastic materials	587	481	419	22
Plastics, basic shapes and forms	238	203	159	17
Other chemical products	236	236	229	0
TOTAL	**$3988**	**$4054**	**$3487**	**−2%**
Exports to U.S.	**$2669**	**$2663**	**$2288**	**0%**
U.S. share, %	**67%**	**66%**	**66%**	**—**

Source: Statistics Canada

TRADE BALANCE: Surplus slips a little

$ Billions (U.S.)	1985	1984	1983	1982
Total exports	$85.3	$83.8	$71.1	$66.6
Total imports	77.1	73.2	60.8	55.3
Trade balance	8.2	10.6	10.3	11.3

Chemical trade is just about in balance

$ Millions (U.S.)	1985	1984	1983	1982
Chemical exports	$3988	$4054	$3487	$3284
Chemical imports	3997	3986	3531	2919
Chemical trade balance	−9	68	−44	365

Source: Statistics Canada

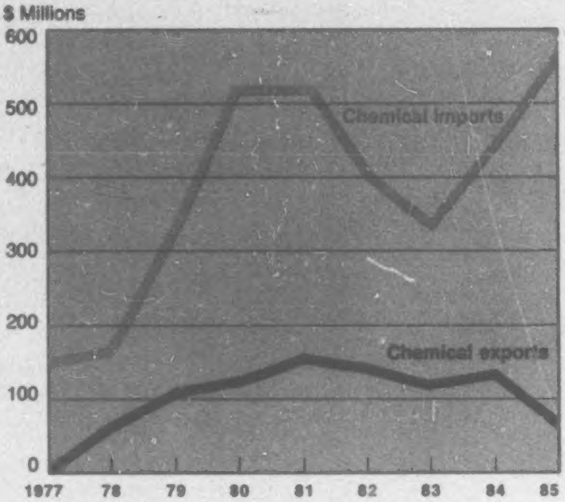
PRICES: For chemicals overall, little change

Price index, 1981 = 100	1985	1984	1983	Change 1984–85
All commodities	118.6	115.4	110.4	3%
Chemicals and chemical products	114.5	113.1	108.8	1
Inorganic industrial chemicals	114.5	112.5	107.9	2
Sulfuric acid	121.7	119.3	117.0	2
Chlorine	130.1	124.6	116.4	4
Organic industrial chemicals	94.5	100.3	98.9	−6
Benzene-toluene-xylene	94.0	89.6	92.4	5
Olefins	83.5	95.4	98.8	−12
Synthetic resins	109.4	111.4	106.8	−2
Polyethylene[a]	90.8	99.0	93.6	−8
Polystyrene	93.6	101.5	102.4	−8
Thermosets	115.1	113.2	107.5	2
Synthetic fibers	101.2	101.5	99.1	0
Pharmaceuticals	141.5	131.5	122.1	8
Paint and varnish	121.6	116.3	113.6	5
Soaps and cleansers	119.1	115.2	111.5	3
Toilet preparations	140.9	135.3	121.3	4
Agricultural chemicals	111.9	107.6	105.9	4
Pigments, lakes, and toners	115.0	112.2	106.0	2
Fertilizers, mixed	100.4	102.0	97.9	−2
Inks	110.4	108.8	109.7	1

a Includes both high and low density. Source: Statistics Canada

5 Foreign Chemical Industries—Mexico

Trade deficit surges as exports plummet



Note: Trade in primary petrochemicals only; does not include secondary chemicals.
Source: Petróleos Mexicanos

DOMESTIC SALES: Up strongly for some

Thousands of metric tons[a]	1985	1984	1983	1982	Change 1984–85
Acetaldehyde	199	212	200	156	−6.8%
Acrylonitrile	96	84	86	71	13.6
Ammonia, anhydrous	1804	1670	1455	1308	8.0
Benzene	17	12	11	13	42.6
Butadiene	110	106	84	66	3.5
Cyclohexane	62	50	51	50	24.3
Dodecylbenzene	100	101	107	111	−1.4
Ethylene oxide	118	112	105	78	5.4
Hexane	48	50	47	54	−4.9
Isopropyl alcohol	61	58	54	47	5.4
Methanol	176	162	140	129	9.0
Polyethylene, high density	134	136	120	120	−1.1
Polyethylene, low density	266	222	251	261	19.9
Styrene	140	125	116	118	12.3
Sulfur	457	455	319	365	0.3
Toluene	97	85	81	86	14.6
Vinyl chloride	275	259	206	139	6.1
o-Xylene	38	32	33	27	20.9
p-Xylene	268	263	131	187	1.9

[a] Domestic sales by Petróleos Mexicanos (Pemex) of primary petrochemicals. Source: Pemex

CHEMICAL IMPORTS: Many show sharp gains

Thousands of metric tons[a]	1985	1984	1983	1982	Change 1984–85
Acetaldehyde	70	70	42	13	0.0%
Acrylonitrile	50	34	28	17	46.4
Benzene	0	0	0	12	—
Butadiene	97	67	45	50	44.8
Cyclohexane	33	26	3	13	29.7
Dichloroethane	0	57	25	0	—
Dodecylbenzene	39	49	55	47	−19.9
Ethylbenzene	6	16	6	16	−61.6
Ethylene	0	0	0	31	—
Ethylene oxide	48	11	0	0	347.8
Isopropyl alcohol	50	44	25	31	15.3
Perchloroethylene	14	15	9	12	−7.1
Polyethylene, high density	42	19	49	17	124.7
Polyethylene, low density	127	63	88	106	103.5
Propylene	26	26	17	22	−0.4
Propylene tetramer	19	12	6	15	58.7
Styrene	112	93	66	61	20.1
Toluene	43	37	0	12	16.4
Vinyl chloride	162	109	75	71	48.8
o-Xylene	9	0	7	10	—
p-Xylene	179	119	25	131	51.2

[a] Imports by Petróleos Mexicanos (Pemex) of primary petrochemicals. Source: Pemex

PRODUCTION: More up than down

Thousands of metric tons[a]	1985	1984	1983	1982	Change 1984–85
Acetaldehyde	145	147	153	149	−1.4%
Acrylonitrile	49	49	55	53	0
Ammonia, anhydrous	2261	2156	2355	2469	4.9
Benzene	178	156	139	96	14.1
Butadiene	18	20	18	15	−9.5
Cyclohexane	32	30	49	35	4.7
Cumene	39	33	37	20	18.8
Dichloroethane	193	220	265	201	−12.[illegible]
Dodecylbenzene	61	51	57	62	20.3
Ethane	1905	1574	1638	1550	21.1
Ethylbenzene	46	31	24	23	48.4
Ethylene	670	643	645	396	4.3
Ethylene oxide	71	97	112	79	−27.1
Hexane	98	95	64	76	3.5
Hydrochloric acid	63	77	79	47	−18.1
Isopropyl alcohol	14	14	12	11	2.6
Methanol	192	197	206	191	−2.4
Nitrogen	46	47	45	39	−1.3
Oxygen	211	200	214	208	5.3
Polyethylene, high density	67	76	82	78	−11.1
Polyethylene, low density	160	134	88	93	19.8
Propylene	207	208	191	158	−0.7
Propylene tetramer	31	35	30	38	−11.5
Styrene	33	30	24	29	9.2
Sulfur, recovered	475	461	377	425	3.0
Toluene	220	216	223	138	1.9
Vinyl chloride	108	132	134	79	−18.1
m- and *p*-Xylene	247	225	197	99	9.8
o-Xylene	44	43	39	16	4.0

[a] Production of Petróleos Mexicanos (Pemex) of primary petrochemicals. Source: Pemex

Foreign Chemical Industries—Eastern Europe 5

In 1985, economic growth slowed somewhat in East Europe and the Soviet Union. Overall industrial output for the region rose 3.9%, short of the goal of 4.1% and down from growth rates of 4.3% in 1983 and 1984.

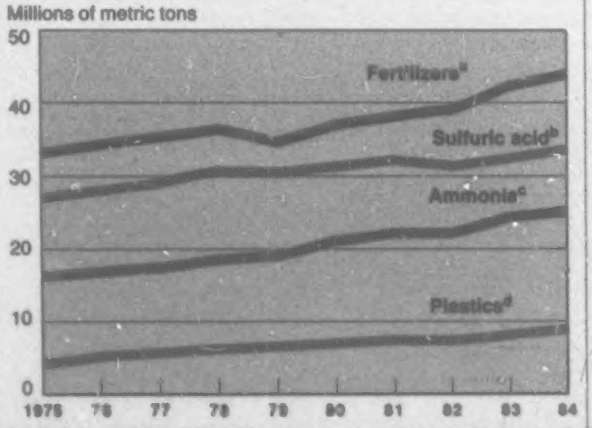
Chemical industry growth also slowed in 1985, hindered like that for other industries by an unusually harsh winter and resulting fuel and energy shortages. Soviet chemical output rose 5%, with mineral fertilizers up 8%, plastics 4%, and pesticides, sodium hydroxide, and sulfuric acid up 3%. Soviet output of fertilizers, plastics, and man-made fibers failed to meet targets.

MAN-MADE FIBERS: Moderate growth in output for most East European countries

Production, thousands of metric tons	1984	1983	1982	1981	Change 1983–84
NONCELLULOSIC FIBERS[a]					
Bulgaria	62	60	52	56	3%
Czechoslovakia	105	105	102	90	0
East Germany	144	144	134	134	0
Hungary	25	21	20	21	18
Poland	154	148	128	119	5
Romania	166	155	151	154	7
U.S.S.R.	644	622	594	573	4
TOTAL	1300	1254	1182	1148	4%
CELLULOSIC FIBERS					
Bulgaria	41	39	38	39	5%
Czechoslovakia	59	58	55	54	2
East Germany	170	165	162	169	3
Hungary	7	6	8	8	9
Poland	76	69	64	64	9
Romania	60	60	58	65	0
U.S.S.R.	652	645	635	646	1
TOTAL	1064	1042	1020	1044	2%

a Excludes olefins and textile glass. **Source:** Textile Economics Bureau

Eastern Europe has been boosting chemical output during the 1980s



a As N, P_2O_5, and K_2O. b 100% H_2SO_4. c Nitrogen content. d Including resins for man-made fibers in U.S.S.R. **Note:** Data for U.S.S.R., Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania.
Sources: Central Intelligence Agency, Department of Agriculture, C&EN estimates

PRODUCTION GROWTH: Rise continues

% annual change in gross output	1985	1984	1983	1982	1981
U.S.S.R. and East Europe					
All industry	3.9%	4.3%	4.3%	2.4%	2.2%
Bulgaria					
All industry	4.0	4.2	4.3	4.6	5.4
Chemicals	3.4	8.2	5.9	6.6	4.0
Czechoslovakia					
All industry	3.4	4.0	2.8	1.1	2.1
Chemicals	3.9	4.5	3.5	1.1	1.7
East Germany					
All industry[a]	4.4	4.2	4.1	3.1	4.7
Chemicals	na	4.3	2.9	4.8	2.7
Hungary					
All industry	1.0	3.2	1.2	2.5	2.4
Chemicals[b]	na	4.0	1.5	1.5	2.3
Poland					
All industry	3.8	5.2	6.4	−2.1	−10.8
Chemicals	2.7	5.0	8.2	0.1	−11.4
Romania					
All industry	4.9	6.7	4.7	1.1	2.6
Chemicals	na	8.2	5.5	1.5	4.0
U.S.S.R.					
All industry[c]	3.9	4.1	4.2	2.9	3.4
Chemicals[c]	5.0	5.0	6.0	3.0	5.5
All industry[d]	na	3.8[e]	3.8	2.4	2.3
Chemicals[d]	na	4.1[e]	6.7	1.5	4.0

a Industrial commodity production. b For state and cooperative industry only. c Figures based on official Soviet statistics. d Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. e Preliminary figure. na = not available. **Sources:** United Nations Economic Commission for Europe, Foreign Broadcast Information Service, and Wharton Econometric Forecasting Associates, based on official national statistics; Central Intelligence Agency

AGRICULTURAL CHEMICALS: Fertilizer supplies generally lower outside U.S.S.R.

Thousands of metric tons	1985	1984	1983	1982	1981
Bulgaria					
Fertilizer supply[a]	950[b]	964	1,009	1,038	1,044
Pesticide supply[c]	na	35.6	33.9	40.4	48.6
Czechoslovakia					
Fertilizer supply[a]	1,734[b]	1,759	1,776	1,741	1,720
East Germany					
Fertilizer supply[a]	1,590[b]	1,566	1,451	1,408	1,726
Pesticide supply[c]	na	26.0	26.0	26.7	27.0
Hungary					
Fertilizer supply[a]	1,338	1,524	1,586	1,528	1,485
Poland					
Fertilizer supply[a]	3,270[b]	3,424	3,182	3,346	3,499
Pesticide supply[c]	12.3	11.1	14.7	16.3	12.4
Romania					
Fertilizer supply[a]	1,135[b]	1,168	1,157	1,077	1,083
U.S.S.R.					
Fertilizer supply[a]	25,400	23,080	22,977	20,152	19,176
Nitrogen[a]	11,430[b]	10,279	10,302	9,038	8,383
Phosphate[a,d]	7,240[b]	6,625	6,465	6,115	5,879
Potassium[a]	6,720[b]	6,167	6,201	4,991	4,905
Pesticide supply[e]	595	576	557	533	504

a Nutrient content basis, as N, P_2O_5, or K_2O. b Estimated. c On basis of active substance. d Includes ground phosphate rock. e On conventional weight basis. na = not available. **Sources:** Department of Agriculture and Foreign Broadcast Information Service, based on official national statistics

PRODUCTION: U.S.S.R. accounts for the bulk of Eastern Europe's chemicals

Thousands of metric tons, unless otherwise noted	1985[a]	1984	1983	1982	1981
U.S.S.R.					
Sulfuric acid, 100%	26,000	25,338	24,714	23,801	24,095
Mineral fertilizers[b]	33,200	30,808	29,733	26,738	25,999
Nitrogen[b]	14,490	13,328	13,014	11,593	10,705
Phosphate[b,c]	8,170	7,705	7,417	7,057	6,836
Potassium[b]	10,530	9,776	9,294	8,079	8,449
Synthetic ammonia[d]	na	17,445	16,904	14,605	14,718
Plastics[e]	5,000	4,819	4,419	4,058	4,089
Sodium hydroxide, 100%	3,100	2,972	2,853	2,783	2,757
Synthetic rubber[f]	na	1,850	1,812	1,795	1,860
Pesticides[g]	595	577	557	533	504
Rubber tires[h] (thousands of units)	65,200	63,700	62,000	61,700	60,500
BULGARIA					
Sulfuric acid, 100%	na	908	861	916	920
Mineral fertilizers[b]	na	690	687	698	710
Nitrogen[b]	na	479	483	459	453
Phosphate[b]	172	211	204	239	258
Synthetic ammonia[d]	na	1,138	1,124	1,033	1,023
Plastics	na	418	398	337	290
Sodium hydroxide, 100%	na	163	147	155	151
Synthetic rubber	na	26	25	25	30
Pesticides[i]	na	20	21	20	20
CZECHOSLOVAKIA					
Sulfuric acid, 100%	na	1,240	1,244	1,252	1,315
Mineral fertilizers[b]	na	1,190	1,175	1,166	1,139
Nitrogen[b]	582	576	591	568	539
Phosphate[b,c]	na	398	378	387	394
Potassium[b,g]	na	216	206	211	206
Synthetic ammonia[d]	na	na	809	726	711
Plastics	1,100	1,039	1,006	956	913
Sodium hydroxide, 100%	na	325	330	324	330
Synthetic rubber	na	71	67	66	63
Pesticides[i]	na	na	16	16	16
EAST GERMANY					
Sulfuric acid, 100%	na	884	926	920	948
Mineral fertilizers[b]	na	4,733	4,714	4,669	4,787
Nitrogen[b]	1,078	959	968	948	967
Phosphate[b,c]	na	308	315	286	360
Potassium[b]	na	3,465	3,431	3,434	3,460
Synthetic ammonia[d]	na	na	1,210	1,167	1,203
Plastics	na	1,085	1,045	990	998
Sodium hydroxide, 100%	na	695	687	695	631
Synthetic rubber	na	152	155	155	155
Pesticides[i]	na	na	54	53	53
Rubber tires[h] (thousands of units)	na	7,764	7,380	7,051	7,026
HUNGARY					
Sulfuric acid, 100%	na	550	606	571	573
Mineral fertilizers[b]	na	1,103	1,110	1,071	1,112
Nitrogen[b]	na	675	684	660	684
Phosphate[b]	na	288	282	269	276
Potassium[b,j]	na	139	140	142	152
Synthetic ammonia[d]	na	na	812	791	819
Plastics	na	383	345	326	314
Sodium hydroxide, 100%[k]	na	194	192	178	180
Pesticides[i]	36	36	36	28	29
POLAND					
Sulfuric acid, 100%	na	2,770	2,786	2,676	2,776
Mineral fertilizers[b]	2,270	2,356	2,323	2,284	2,241
Nitrogen[b]	1,254	1,369	1,341	1,298	1,274
Phosphate[b]	889	869	872	868	866
Potassium[b,j]	127	118	111	118	101
Synthetic ammonia[d]	na	na	1,430	1,384	1,465
Plastics	na	593	535	451	476
Sodium hydroxide, 100%	na	379	392	363	400
Synthetic rubber	126	119	120	100	111
Pesticides[i]	na	na	9	9	8
Rubber tires[h] (thousands of units)	8,541	8,104	6,695	5,322	6,134
ROMANIA					
Sulfuric acid, 100%	na	1,915	1,941	1,600	1,814
Mineral fertilizers[b]	3,096	3,073[f]	2,913	2,692	2,640
Nitrogen[b]	na	2,212[f]	2,091	2,008	1,822
Synthetic ammonia[d]	na	na	2,723	2,583	2,383
Plastics	628	655	633	591	584
Sodium hydroxide, 100%	na	805	745	760	767
Synthetic rubber	156	159	147	160	146
Pesticides[i]	na	53	48	45	43

a Approximate figures or estimates. b Nutrient content basis, as N, P_2O_5, or K_2O. c Including production of ground phosphate rock for direct applications and phosphate animal feeds. d Nitrogen content. e Including resins for man-made fibers. f Estimated. g On conventional weight basis. h For all motor vehicle tires, excluding aircraft and bicycle tires. i On basis of active substance. j Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. k Including regenerated NaOH. na = not available. **Sources:** Central Intelligence Agency, Department of Agriculture, Foreign Broadcast Information Service, Commerce Department, and Wharton Econometric Forecasting Associates, based on official national statistics

SOVIET FOREIGN TRADE: Overall surplus drops sharply

$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Exports[a]	$87,895[b]	$91,492	$91,652	$87,168	$79,377	$76,437	$64,912	$52,435	$45,227	$37,269	$33,407
Imports[a]	83,819[b]	80,353	80,440	77,847	73,158	68,473	57,958	50,798	40,926	38,212	37,070
Trade balance	4,076[b]	11,139	11,212	9,321	6,219	7,964	6,954	1,637	4,301	−943	−3,663
Chemical exports[a]	na	na	2,422	2,309	2,380	2,139	1,606	1,284	1,063	939	1,027
Chemical imports[a]	na	na	4,070	3,886	4,031	3,732	2,803	2,188	1,850	1,668	1,747
Chemical trade balance	na	na	−1,648	−1,577	−1,651	−1,593	−1,197	−904	−787	−729	−720

a Free on board. b Approximate values. na = not available. **Sources:** Central Intelligence Agency, Wharton Econometric Forecasting Associates, based on official Soviet statistics and exchange rates

KOREA

INDUSTRY TRENDS: Growth moderates

Index, 1980 = 100	1985	1984	1983	1982	Change 1984–85
Chemicals, petroleum, coal, rubber, and plastic products					
Production	146.6	140.7	123.7	105.9	4%
Shipments	138.1	132.6	119.5	102.4	4
Inventories	132.4	125.2	119.5	115.4	6
Industrial chemicals					
Production	129.4	126.4	116.0	101.8	2
Shipments	141.5	134.4	124.5	108.2	5
Inventories	137.0	117.3	114.2	121.1	17
Other chemical products					
Production	171.7	160.8	141.7	122.5	7
Shipments	168.6	158.7	139.2	119.4	6
Inventories	183.8	159.3	141.6	118.5	15
Rubber products					
Production	158.1	158.4	120.3	99.2	0
Shipments	158.4	158.2	120.1	98.3	0
Inventories	139.4	138.2	99.8	87.2	1
Plastic products					
Production	153.6	145.3	124.2	92.9	6
Shipments	154.7	146.1	123.6	92.6	6
Inventories	130.6	139.9	132.0	121.9	−7
All manufacturing					
Production	167.1	160.6	139.0	119.4	4
Shipments	160.6	153.6	135.8	116.2	5
Inventories	150.3	138.0	126.0	126.5	9

Source: Bureau of Statistics of the Korean Economic Planning Board

FOREIGN TRADE: Chemical deficit stable

$ Millions	1985	1984	1983	1982
Exports[a]	$30,283	$29,245	$24,445	$21,853
Imports[b]	31,136	30,631	26,192	24,251
Trade balance	−853	−1,386	−1,747	−2,398
Chemical exports	936	845	677	670
Chemical imports	2,789	2,709	2,242	2,051
Chemical trade balance	−1,853	−1,864	−1,565	−1,381

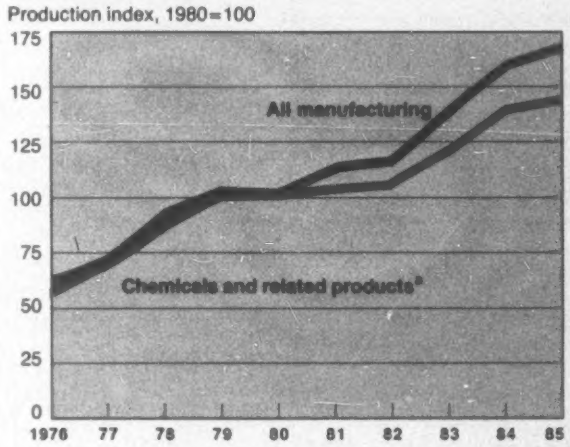
a Free on board. b Includes cost, insurance, freight. **Source:** Korean Office of Customs Administration

PRODUCTION: Down for some ag chemicals

Thousands of metric tons	1985[a]	1984	1983	1982	Change 1984–85
Sulfuric acid	2028	1975	1610	1596	3%
Complex fertilizers	1944	1861	1614	1667	4
Ammonia	538	565	523	661	−5
Urea fertilizers	839	858	737	788	−2
Ethylene	562	526	491	374	7
Polyethylene	353	317	279	218	11
Polyester fibers	291	265	217	189	10
Sodium carbonate	251	248	231	186	1
Sodium hydroxide	229	215	202	166	6
Benzene	216	171	159	120	26
Insecticides	84	110	87	58	−23
Synthetic detergents	68	62	57	52	10

a Preliminary figures. **Source:** Bureau of Statistics of the Korean Economic Planning Board

After two strong years, growth in production slowed in 1985



a Includes petroleum, coal, rubber, and plastic products.
Source: Bureau of Statistics of Korean Economic Planning Board

AUSTRALIA

PRODUCTION: Higher for most chemicals

Thousands of metric tons	1985[a]	1984[a]	1983[a]	1982[a]	Change 1984–85
Chemicals and acids					
Hydrochloric acid, 100%	58	57	60	55	2%
Nitric acid, 100%	197	189	189	180	4
Sulfuric acid, 100%	1774	1726	1782	2027	3
Ammonium sulfate	242	217	200	207	12
Superphosphate[b]	2582	2663	2986	3568	−3
Plastics and resins	na	822	720	801	na
Synthetic detergents	226	228	220	211	−1
Unsupported plastics film, sheeting	157	139	na	119	13
Polyethylene[c]	118	107	na	82	10
Polyvinyl chloride[d]	14	14	17	18	2

a Years ending June 30. b Includes double and triple superphosphates and ammonium phosphate expressed in terms of single phosphate (22% P_2O_5 equivalent). c Low and high density. d Including copolymers. na = not available. **Source:** Australian Bureau of Statistics

FOREIGN TRADE: Chemical deficit widens

$ Millions	1985[a]	1984[a]	1983[a]	1982[a]
Exports[b,c]	$23,215	$21,842	$20,184	$20,639
Imports[d]	22,593	21,374	20,004	24,365
Trade balance	622	468	180	−3,726
Chemical exports[b,c]	426	455	431	430
Medicinal products	95	108	102	95
Chemical imports[d]	1,986	1,959	1,671	1,955
Organic chemicals	523	554	441	530
Resins, plastic materials	442	441	343	460
Medicinal products	229	201	182	166
Chemical trade balance	−1,560	−1,504	−1,240	−1,525

a Years ending June 30. b Free on board. c Includes re-exports. d Values for customs purposes, free-on-board basis. **Source:** Australian Bureau of Statistics

CHINA

PRODUCTION: Fibers continue strong growth but agricultural chemicals slump

Thousands of metric tons, unless otherwise noted	1985	1984	1983	1982	Change 1984–85
Fertilizer[a]	13,350	14,602	13,789	12,781	−9%
Nitrogen (N)	na	12,210	11,094	10,219	na
Phosphate (P_2O_5)[b]	na	2,360	2,666	2,537	na
Potash (K_2O)	na	32	29	25	na
Sulfuric acid, 100%	6,690	8,172	8,696	8,175	−18
Sodium hydroxide	2,347	2,222	2,123	2,073	6
Sodium carbonate	2,000	1,880	1,793	1,735	6
Calcium carbide	na	1,846	1,808	1,675	na

Thousands of metric tons, unless otherwise noted	1985	1984	1983	1982	Change 1984–85
Plastics	1,208	1,160	1,121	1003	4%
Man-made fibers	945	735	541	517	29
Synthetic detergents	na	810	677	569	na
Ethylene	651	648	654	565	0
Pesticides	205	299	331	457	−31
Pharmaceuticals	57	52	48	42	10
Synthetic rubber	na	174	169	136	na
Rubber tires[c]	18,527	15,345	12,710	8640	21

a Nutrient content. b Including production of ground phosphate rock for direct application and phosphate animal feeds. c In thousands of units, not including wheelbarrow and bicycle tires. na = not available. **Sources:** State Statistical Bureau of the People's Republic of China, Chinese Ministry of Chemical Industry, Central Intelligence Agency

CHEMICAL IMPORTS: Up sharply

$ Millions[a]	1984	1983	1982	Change 1983–84
Fertilizers[b]	$ 700	$ 569	$ 622	23%
Plastic materials, resins	1133	575	634	97
Chemical elements and compounds	589	576	521	2
Dyeing, tanning, and coloring materials	86	117	141	−26
Medicinal products	62	43	34	44
Essential oils, perfume, and cleansing materials	51	40	22	28
Mineral tar and crude chemicals[c]	5	7	1	−23
Explosives and pyrotechnic products	2	1	1	143
Other chemical products	302	308	195	−2
TOTAL	**$2931**	**$2235**	**$2170**	**31%**

a Free on board. b Manufactured. c From coal, oil, and natural gas. **Source:** Central Intelligence Agency, estimated from data reported by China's trade partners

CHEMICAL EXPORTS: Moderate growth

$ Millions[a]	1984	1983	1982	Change 1983–84
Chemical elements and compounds	$ 608	$ 541	$ 581	12%
Medicinal products	248	237	224	5
Explosives and pyrotechnic products	122	112	110	9
Essential oils, perfume, and cleansing materials	120	110	98	9
Dyeing, tanning, and coloring materials	89	81	71	10
Plastic materials, resins	57	54	43	5
Mineral tar and crude chemicals[b]	14	16	31	−9
Fertilizers[c]	1	3	3	−69
Other chemical products	138	134	137	3
TOTAL	**$1398**	**$1289**	**$1298**	**8%**

a Free on board. b From coal, oil, and natural gas. c Manufactured. **Source:** Central Intelligence Agency, estimated from data reported by China's trade partners

TAIWAN

INDUSTRY TRENDS: Growth slows

Industrial production indexes, 1981 = 100	1985	1984	1983	1982	Change 1984–85
All manufacturing	132.9	132.0	117.0	101.3	1%
Chemical materials	149.0	139.6	115.4	99.6	7
Basic chemicals	125.7	118.6	107.1	99.7	6
Petrochemicals	154.7	144.8	114.3	95.3	7
Fertilizers	65.6	75.2	74.0	72.8	−13
Synthetic fibers	146.7	136.6	117.8	104.1	7
Plastics and resins	164.6	153.1	123.8	105.0	8
Chemical products	147.1	141.8	125.2	116.4	4

Source: Taiwan Ministry of Economic Affairs

FOREIGN TRADE: Deficit down for chemicals

$ Millions	1985	1984	1983	1982
Exports[a]	$30,717	$30,456	$25,123	$22,204
Imports[b]	20,107	21,959	20,287	18,888
Trade balance	10,610	8,497	4,836	3,316
Chemical exports[a,c]	1,341	1,244	1,041	1,012
Chemical imports[b,c]	2,965	3,203	2,814	2,312
Chemical trade balance	−1,624	−1,959	−1,773	−1,299

a Free on board. b Includes cost, insurance, and freight. c For chemicals and chemical products. **Sources:** Taiwan Council for Economic Planning & Development, Taiwan Ministry of Finance, C&EN estimates

PRODUCTION: Some gains, some losses

Thousands of metric tons, unless otherwise noted	1985	1984	1983	1982	Change 1984–85
Man-made fibers	1028	970	840	730	6%
Sulfuric acid	733	762	678	685	−4
Polyvinyl chloride	633	634	522	459	0
Ethylene	792	660	499	452	20
Vinyl chloride	511	492	458	434	4
Ammonium sulfate	507	434	381	373	17
Ammonia, anhydrous	252	327	378	386	−23
Sodium hydroxide	387	351	295	359	10
Xylene[a]	310	334	275	230	−7
Compound fertilizer	249	301	275	247	−17
Propylene	415	341	250	225	22
Hydrochloric acid	228	241	212	191	−5
Benzene[a]	322	281	182	130	14
Urea	139	179	171	175	−22
Calcium superphosphate	132	177	159	160	−25
Ethylene glycol	199	189	151	120	5
Oxygen[b]	347	198	125	164	75
Toluene[a]	172	195	115	113	−12
Paints	130	123	108	97	6

a Millions of liters. b Millions of cubic meters. **Source:** Taiwan Council for Economic Planning & Development

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CHEMICAL & ENGINEERING

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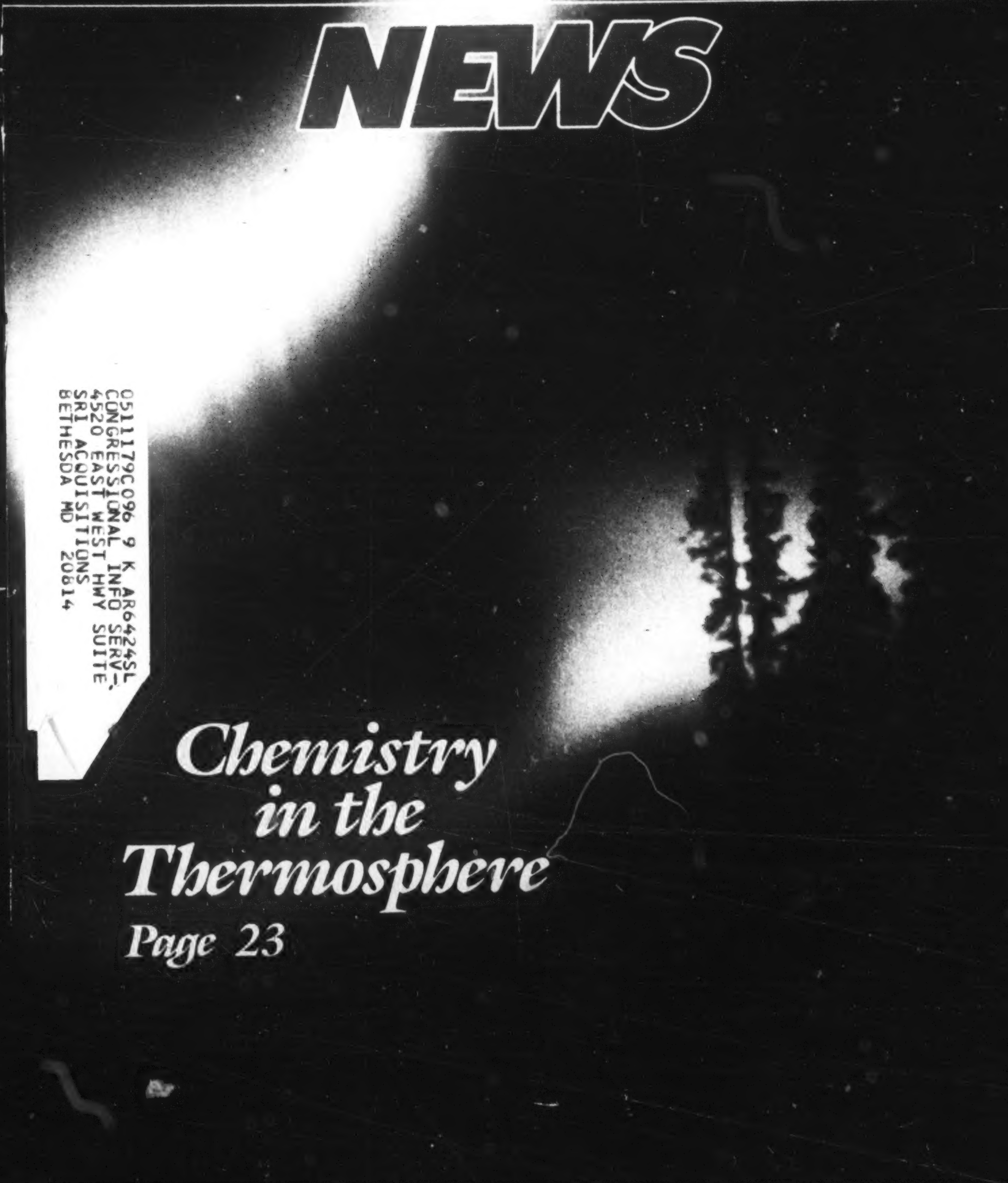

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Chemistry in the Thermosphere

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CHEMICAL & ENGINEERING
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JUNE 16, 1986

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- **Caltech team invents machine to determine automatically the sequence of bases in genes or gene fragments.** **Page 4**
- **Congress holds hearings on report of Presidential commission that studied the space shuttle accident, discusses recommendations.** **Page 5**
- **League of Women Voters launches campaign to curb improper disposal of household hazardous wastes.** **Page 5**
- **GAO says Defense Department's Bigeye binary nerve gas bomb is not ready for production.** **Page 6**
- **Large chemical, other firms invest in new insurance company for protection against high liability claims.** **Page 6**

Cover: Aurora borealis in northern sky. Photo courtesy of Geophysical Institute, University of Alaska

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Business

Capital expenditures of foreign affiliates of U.S. chemical companies forecast to be $3.22 billion this year, a 22% hike over 1985. **Page 9**

Government

House version of supplemental appropriations bill requires DOD to fund research at 10 universities; Senate disagrees. **Page 12**

Joint hearing of House subcommittees on bill to regulate biotechnology products prompted by lack of Administration policy. **Page 13**

Science

Method of functionalizing alkanes, using polyoxo metal complexes as catalyst, entails unusual mechanism and products. **Page 15**

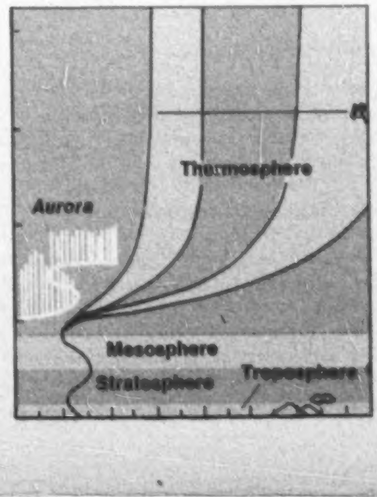
Recent research on geometry of carbon clusters in molecular beams challenged; some claim other data must be considered. **Page 16**

Value of plant germ plasm, fear of erosion of the world's genetic base debated by developing and developed countries. **Page 17**

Technology

USS Chemicals provides funds, personnel, and Neville Island plant site to Coast Guard for hazardous spill emergency exercise. **Page 18**

Rent-a-chemist service supplies temporary help to laboratories and companies, gives employment to consultants, specialists. **Page 19**



Special Report

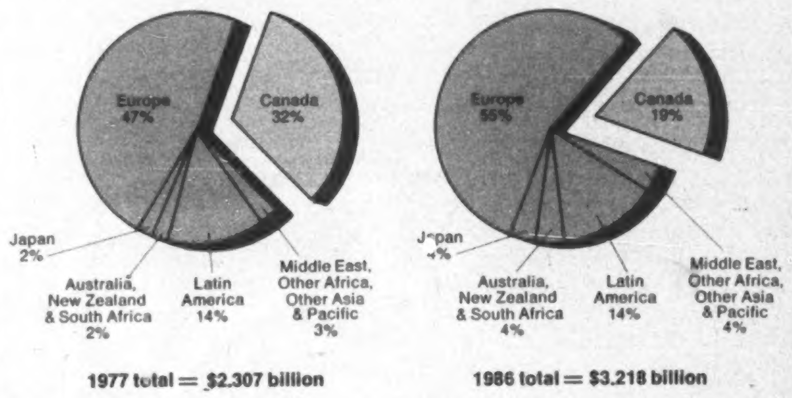
Knowledge of the thermosphere, where temperature increases with altitude, and the ionosphere, which produces magnetic disturbances on the ground, has increased since the rocket and satellite probes of the 1950s. **Page 23**

U.S. Chemical Firms' Capital Spending Abroad To Increase

According to latest Department of Commerce survey, such spending this year will rise about 22% from 1985 to $3.22 billion

William J. Storck, C&EN New York

Canada's spending has lost ground to other areas



Source: Commerce Department

After a number of years in the doldrums, capital expenditures by foreign affiliates of U.S. chemical companies are forecast to show a healthy increase this year, according to the Commerce Department's latest survey of spending plans for new plant and equipment overseas.

The survey, based on figures gathered at beginning of 1986, indicates that such spending abroad this year will rise 22% from 1985 to almost $3.22 billion. Although that projection is down 5% from an estimate made six months earlier, the projected rate of increase is still well above the 0.5% increase actually achieved in 1985. And the 22% rise is well above the forecast for the increase in total capital spending by chemical companies in 1986, estimated at just 5.5% over 1985.

It is not unusual for the estimate to fall during the year as companies face economic reality. In the 1981–85 period, only 1981 spending turned out higher than was first forecast, and it was only 3% higher. When the final tallies were in, spending for 1982 through 1984 was more than 20% less than first forecast, and 1985 spending was 11% less. The same pattern has prevailed recently for all industries.

A commentary on the survey, written by Commerce Department analyst Jeffrey H. Lowe, says of the total survey: "The downward adjustment for 1985 continues a recent pattern in which spending estimates made near the end of the year are much lower than those made six months earlier. The pattern, established during a period of prolonged sluggish growth abroad, largely results from the cancellation of some projects and the deferral of others into the following year."

This year might prove another exception to the pattern, however. "Spending plans in manufacturing industries in 1986 may be revised up if the recent steep decline in oil prices leads to better-than-expected economic growth abroad," Lowe says. "In particular, the price decline may have a positive effect on chemical affiliates, because petroleum feedstocks represent a significant portion of their production costs."

Final capital spending is usually lower than first forecast

	% change from first forecast[a]					
	1986	1985	1984	1983	1982	1981
Developed countries	−1%	−11%	−20%	−19%	−19%	−28%
Canada	−8	−16	−48	−8	8	−34
Europe	9	−7	−3	−22	−29	−24
Japan	−13	−10	9	11	27	−50
Australia, New Zealand, and South Africa	−10	−35	−20	−24	−41	−15
Developing countries	−18	−9	−21	−37	−44	−5
Latin America	−27	−8	−20	−43	−50	12
Other Africa	−19	0	−36	−55	na	na
Middle East	0	−38	40	0	na	na
Other Asia and Pacific	47	−14	−27	−8	−9	−6
Average change	−5%	−11%	−20%	−23%	−25%	3%

[a] % change between first forecast and final numbers when available. Figures for 1986 are for first and latest forecasts. Figures for 1985 are for first forecast and latest estimate. na = not available. Source: Commerce Department

After years of depressed spending, foreign capital expenditures are slated to pick up this year

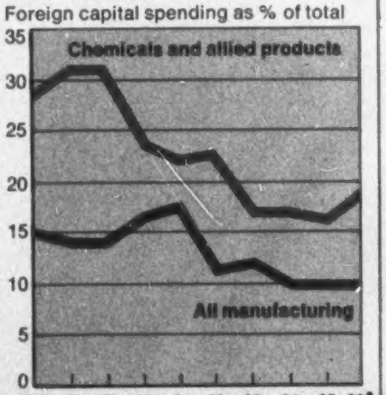
$ millions, for chemicals and allied products	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Developed countries	$2641	$2149	$2146	$1903	$2529	$2304	$2356	$2625	$2026	$1923
Canada	625	471	507	425	862	655	494	921	752	732
Europe	1773	1480	1440	1285	1476	1475	1701	1475	1115	1086
Japan	129	99	100	78	90	70	88	163	91	49
Australia, New Zealand, and South Africa	114	99	99	115	101	104	73	66	68	56
Developing countries	577	483	474	417	534	664	608	725	434	384
Latin America	432	371	377	303	400	542	511	435	345	324
Other Africa	13	14	7	9	12	6	8	11	10	9
Middle East	10	5	7	6	4	5	20	23	30	21
Other Asia & Pacific	122	93	83	99	118	111	69	256	49	30
Total	$3218	$2632	$2620	$2320	$3063	$2968	$2964	$3350	$2460	$2307
% change	22.3%	0.5%	12.9%	−24.3%	3.2%	0.1%	−11.5%	36.2%	6.6%	−15.6%

Note: Capital spending by majority-owned foreign affiliates of U.S. companies. **Source:** Commerce Department

Even if the chemical affiliates spend what they are planning or even a little more than what they intend to spend this year, foreign capital expenditures still will be below the record in 1979. The current forecast of $3.22 billion for 1986 is almost 4% less than spending in 1979. Given intervening inflation, capital expenditures in real dollars are thus far below their historic high.

Another measure showing that foreign capital spending is considerably below traditional levels is its relationship to another Commerce Department survey of total capital spending by U.S. chemical companies. Foreign spending by U.S. companies will be about 19% of total capital spending, according to the latest Commerce Department forecast. That percentage is up from last year's 16%, but considerably less than the 30% range where the ratio was running in the second half of the 1970s. Even in the first three years of the 1980s, the ratio still was more than 20%.

Foreign spending remains low as percent of total



ª Forecast.

The declines in chemical capital spending abroad in relation to both historic rates and to total capital spending may indicate a number of economic factors. The first is simply that foreign spending is not so important to companies as they once thought. In the past few years, some chemical analysts were saying that, because of the high value of the dollar against foreign currencies, U.S. chemical companies would have to build overseas to compete. At least some of those analysts are now changing their tune and adopting the more traditional advice of building where the feedstock and expertise are—in other words, where the company can produce at the lowest cost.

A second factor is that fewer companies are making big investments overseas. Many chemical companies, such as Monsanto and Union Carbide, have much less of an overseas presence than they did in the 1970s and therefore are spending little if anything overseas.

A third, and probably most important, reason for the near term is that the foreign economic situation is about the same as that in the U.S., and in some countries it is worse. Faced with stagnant markets in many high-use areas, chemical companies have no need to build new plants and thus must content themselves with maintaining and upgrading existing plants.

As is traditional, the vast majority of capital expenditures by chemical affiliates in 1986 will go to industrialized countries, specifically those in Europe. Over the years industrialized countries have received a little more than 80% of spending on new plant and equipment, and developing nations have received the remaining 20% or so. In 1986, industrialized countries are forecast to get 82% of spending, the same as in both 1984 and 1985.

Nevertheless, the breakdown of spending among developed countries has changed. In the mid-1970s, Canada, the U.S.'s largest single trading partner, received about 32% of total foreign capital spending and about 38% of foreign capital spending within developed countries. At the same time, Europe received 47% of total foreign capital spending and almost 57% of that spent within developed nations. But in the 1986 forecast, Canada's share has declined to 19% of total foreign capital spending and 24% of that spent in developed countries, and Europe's share has grown to 55% of total foreign spending and 67% of total developed country spending for chemicals. Nonetheless, Canada still will get a healthy increase, according to the forecast for this year, rising almost 33% from 1985 to $625 million. ◻

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CHEMICAL & ENGINEERING NEWS

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SPACE SHUTTLE

Panel blames accident on faulty joint, mismanagement
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News of the Week

- **EPA Administrator Thomas must grapple with some tough problems—Superfund phasedown, RCRA, and ozone regulation.** Page 6
- **Supreme Court rules FDA need not set regulations on hazardous substances that unavoidably get into food.** Page 7
- **Henley Group forms medical and scientific technologies firm centered on Fisher Scientific.** Page 7
- **OSHA's new rules lower amount of asbestos that can be present in the workplace.** Page 7
- **NSF funds two new laboratories for ultralow-temperature research.** Page 8
- **Beckman Institute, for research on problems at the chemistry/biology interface, to be established at Caltech.** Page 8

Cover: Launch of space shuttle *Challenger* from Kennedy Space Center three years ago. Photo courtesy of NASA

International Business

BP Chemicals is striving to be a leading supplier of polyethylene in Western Europe; Bhopal has brought new legislation, change in operating practices for India's chemical industry. **Page 19**

Government

EPA needs more time, more money to re-evaluate pesticides now on the market, General Accounting Office reports. **Page 24**

Parsons Award

Norman Hackerman, retired from the presidency of Rice University, is the recipient of ACS's Charles Lathrop Parsons Award. **Page 26**

Science

Quasicrystalline metal alloys seem to have both ordered structure and fivefold symmetry, research indicates. **Page 35**

Education

National telephone survey of 2000 adults done in attempt to gain some measures of scientific literacy. **Page 37**

Technology

Energy policy experts fear that complacency due to the current oil glut will leave the U.S. unprepared for next energy crisis. **Page 39**

Preliminary Program

Highlights of ACS national meeting to be held in Anaheim in September include division symposia, preregistration coupon. **Page 43**

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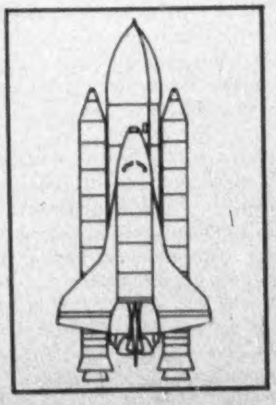


News Focus

One faulty joint on a solid booster rocket led to the death of seven crew members of space shuttle *Challenger* and to NASA's loss of face. Presidential commission investigating the accident recommends redesign of the joint or its seal, review of space agency's structure, and return to the "safety first" pledge. **Page 9**

Scientists Seek To Define, Determine Scientific Literacy

Consensus on meaning has been difficult, though survey makes an attempt at measuring general public's understanding

James H. Krieger, C&EN Washington

That the general public should have a greater degree of scientific and technological literacy is a proposition on which most members of the scientific community readily agree. Many recent studies of deficiencies in education, particularly in early science education, make just this point.

Defining the terms, however, is another matter. It isn't so easy to achieve a consensus on what really constitutes a scientifically or technologically literate individual.

"Scientific literacy is one of those terms that is more often used than defined," says Jon D. Miller, director of the Public Opinion Laboratory at Northern Illinois University. "The failure to examine and specify the meaning of scientific literacy has been the source of much of the confusion surrounding the issue."

Miller and a few other scientists took a stab at examining and specifying the meanings of scientific literacy during the recent annual meeting of the American Association for the Advancement of Science, held in Philadelphia. Noting that "there is more consensus on what constitutes scientific illiteracy than on what constitutes scientific literacy," Miller presented results of a survey that provide, as he put it, some new measures of scientific illiteracy. The analysis found a mixture of understanding and misunderstanding in the American public. But, Miller says, "It is bits and pieces without a theme."

Miller points out that literacy has two distinct and quite different meanings. The older meaning of the term refers to being learned. The second meaning refers to the ability of an individual to read and write at a functional level. He notes that the development of scientific literacy by a broader public did not become a subject of systematic study until the 1930s, when educators began to think about defining and measuring "scientific attitude." On the basis of that and later developments, he says, "The combination of two dimensions—an understanding of the norms of science and knowledge of major scientific constructs — may be viewed as the traditional meaning of scientific literacy as applied to broader populations."

F. James Rutherford, chief education officer for AAAS, thinks that "familiarity" with science is quite enough. Familiarity, he says, is a soft notion that he uses to make a distinction with educational terms like mastery learning, competence, or even the newer term literacy. He says he doesn't much like the term literacy, though he uses it, because of its bookish connotation and sense that what science is might be captured somehow by reading the right material.

"Whatever science is—and that's the starting place for figuring out what we want people to know—it's not a simple thing," Rutherford emphasizes. Science, he says, can be thought of as a body of ideas, as a way of thinking and investigating, and as something the products of which affect people's lives and determine how people live.

One of the aspects of science that people should have assimilated at the end of a process of learning, Rutherford says, is some sense of what the scientific world view is, that is to say, what the world looks like and seems like from the science viewpoint. And those aspects should be known in such a way that it is understood what a fact is, and, at a higher level, how facts relate to scientific laws and to other ideas. At a more general level still are the theories and models that organize facts, laws, and notions into larger areas such as gravitation, statistics, or weather systems, and, higher still, subjects like Newtonian universe, organic evolution, and plate tectonics. Another facet, moreover, is the set of beliefs shared by the people working in science—for example, that the world of phenomena is rationally understandable and not capricious, or that individual observations are subject to uncertainty but that the phenomena are consistent.

Respondents report degree of comfort with terms

Term	Clear understanding	General sense	Little understanding
Molecule	32%	40%	28%
DNA	16	27	57
Radiation	31	51	19
Scientific study	33	50	17

Among the aspects of science not understood, Rutherford says, is that it is not only personal. "It's not just Einstein out there thinking up things about the world," as he puts it. "It's a collective social activity. It's a collaborative activity."

In short, Rutherford says, "What I'm trying to indicate is that these aspects of the enterprise—that it's quantitative, it's qualitative, it's large-scale, it's individual, it has values, it has an ethos, and so forth—need to be looked at."

Rutherford adds that the relationship between science and technology is perhaps as crucial as any other aspect. And it's not a simple relationship. They are different things, with different histories, different premises, and different purposes. And yet the overlap is large and increasing, and there is now an interdependency not only of technology on science but also the reverse. That, Rutherford says, ought to be part of the understanding.

Rustum Roy, director of the science, technology, and society program at Pennsylvania State University, agrees. Technological literacy, he says, is not merely analogous to scientific literacy. Roy quotes a writer as noting that there are two kinds of problems in life, one called convergent, the other divergent. Convergent problems can be solved, divergent problems simply can be addressed. Technological literacy, Roy says, is a divergent problem. It is one to be discussed, not solved.

Technological literacy is a complex, multidimensional reality, Roy notes. It means something different to different people. To Roy, it is equivalent to what he calls TC^3: comfort with, competence in, and control by a person of his or her life in the technological environment. Roy uses the metaphor of a tourist in a foreign country not knowing the language. One manages, he points out, but gives up autonomy and is usually led around by others. "The level to aim for," Roy says, "is to give people a Berlitz course in technology so they will have that level of functioning in the world in which they really live."

For the survey attempting to gain some measures of scientific literacy, the Public Opinion Laboratory collected data from a national telephone survey of 2000 adults. The interviews were conducted during last November and December. The survey was sponsored by a grant from the Science Indicators Unit of the National Science Foundation.

To gain an idea of people's ability to use some of the basic vocabulary of science, the survey included a series of items asking respondents to indicate their understanding of four terms: molecule, DNA, radiation, and scientific study. Miller says that other, earlier surveys using probes to explore the depth of understanding of selected terms found that about half of those people who report a clear understanding of a term are able to describe or define it adequately.

Statements gauge acceptance of scientific paradigms

Statement	Agree	Not sure	Disagree
Perceptions of the universe: "In the entire universe, it is likely that there are thousands of planets like our own on which life could have developed."	68%	9%	24%
Acceptance of plate tectonics: "The continents on which we live have been moving their location for millions of years and will continue to move in the future."	81	9	11
Acceptance of evolution: "Human beings as we know them today developed from earlier species of animals."	47	7	46
Belief in lucky numbers: "Some numbers are especially lucky for some people."	40	4	56
Rocket launchings and weather changes: "Rocket launchings and other space activities have caused changes in our weather."	41	12	47
Belief in extraterrestrial visitors: "It is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations."	43	11	46
Attitude toward planning for the future: "It is not wise to plan ahead because many things turn out to be a matter of good or bad luck anyway."	20	2	78
Attitude toward scientists: "Because of their knowledge, scientific researchers have a power that makes them dangerous."	53	4	44
Deference to experts and leaders: "In this complicated world of ours, the only way we can know what is going on is to rely on leaders and experts who can be trusted."	57	2	41

"It is clear," says Miller, "that a substantial majority of Americans do not have a sufficient vocabulary or comprehension of concepts to utilize a wide array of scientific communication. If a newspaper article or television report depends on some understanding of what a molecule is and how something might change it, at least two thirds of the American audience will have difficulty following the material."

A group of questions relating to astrology sought to examine the ability of people to distinguish between science and pseudo-science. A substantial minority of Americans appear to have some difficulty in making the distinction, Miller says. Two of five people give some credibility to astrology and 7% (which corresponds to about 12 million adults if extrapolated to the entire population) reported changing their actual behavior because of astrology reports.

Miller notes that another important dimension of scientific literacy concerns the knowledge and acceptance of some of the major scientific paradigms of the day. This area, he notes, is slightly more difficult because the spirit of scientific inquiry doesn't demand slavish adherence to every paradigm. At the same time, science does require the use of evidence in challenging a paradigm, and, Miller says, the typical nonscientist is ill-equipped to undertake that kind of dialogue.

So the survey included an area concerning basic theories and concepts. Miller notes that the degree of acceptance of certain scientific paradigms may be helpful in understanding the context in which scientific information is received and processed by the public. The survey, Miller says, found on examining people's views that they displayed a mixture of correct understanding and of basic misunderstanding. □

Older Chemists Continue To Be Targets in Mass Terminations

Michael Heylin, C&EN Washington

The serious impact of continued manpower cuts by chemical and oil companies on the chemical profession is confirmed by the latest American Chemical Society report on mass terminations of chemists and chemical engineers. The newest report, prepared by the society's Committee on Professional Relations (CPR), details investigation of 10 such terminations that occurred between June 1983 and April 1986 and cost the jobs of more than 200 chemical professionals. As has been the case in recent times, older chemists seem to have borne a heavy burden.

Some of the bigger cutbacks reported involve research operations of petroleum concerns. The closing of the Gulf Research & Development Co. facility in Harmarville, Pa., after Gulf's merger with Chevron Oil cost the jobs of more than 70 chemists and chemical engineers. Another 35 chemical professionals lost their employment at Occidental Research Corp., Irvine, Calif., and 20 were involved in a cutback at the Texaco Research Center in Beacon, N.Y. The other seven terminations covered in the report involved 21 chemical professionals at Wright Chemical, 19 at U.S. Steel, 15 at Allied-Signal, 11 at Occidental Petroleum, seven at SmithKline Beckman, and three each at Stauffer Chemical and Penn Central.

CPR also has verified six other mass terminations and is investigating them. Those occurred between July 1984 and June 1986. They were at American Home Products, Atlantic Richfield, Betz Laboratories, Koppers, PPG Industries, and Uniroyal.

The committee defines a mass, or multiple, termination as "a situation in which the employment of three or more chemists or chemical engineers is terminated within a six-month period for reasons other than continuing evidence of previously documented inadequate performance, completion of a contract, or cause."

The latest report is the 23rd in a series produced by CPR since 1974. The reports compare the performance of employers involved in mass terminations with seven standards spelled out under ACS's Professional Employment Guidelines (PEG). Average compliance with those standards for the 10 terminations covered in the latest report is 43%—the same rate as for the 195 terminations analyzed in the previous 22 reports.

Those reports are all developed by CPR's Subcommittee on Professional Standards & Ethics, which in writing them seeks information both from the employers involved and from the terminees. About two thirds of employers respond with data. For the latest report, only two—SmithKline and Wright Chemical—did not.

For the latest report, CPR also received assistance from the Mid-Hudson, North Jersey, Orange County, Pittsburgh, Southeastern Tulsa, and Western New York local sections in gathering data from individual terminees. CPR also invites individuals either involved in, or aware of, mass terminations to contact the American Chemical Society, Office of Professional Relations, 1155—16th St., N.W., Washington, D.C. 20036; phone (202) 872-4431. That office also will provide, on request, copies of all CPR termination reports as well as a summary list of multiple terminations that have occurred within the past 10 years.

The seven PEG standards involved in those reports include length of employee service, rehire privileges, severance pay, advance notice, protection plans, assistance in finding other employment, and pension vesting.

The guideline on employee service states that those with a minimum of 10 years of service should not be terminated except for inadequate performance or cause. It has always been poorly complied with and compliance has deteriorated further in recent years. Such older employees were involved in all 10 of the terminations covered in the latest report. They also have been involved in all but five of the 47 ter-

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after 10 years' service.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination at same rate of contribution as before. Employee would have additional 31-day grace period.

Rehire privileges. Rehire privileges should be carefully explained to terminees.

minations analyzed by CPR since 1984. And of the grand total of 205 terminations examined by the committee since 1974, only 24% did not involve employees with 10 or more years of service.

Older employees were particularly hard hit at Texaco, where 14 of the 20 chemical professionals terminated had more than 10 years of service, and at U.S. Steel, where 12 of the 19 losing their jobs were in this senior category. According to data from terminees, the three chemists involuntarily retired by Stauffer were 55 years of age or older, as were the three chemical professionals similarly retired by Penn Central.

The guideline on rehire privilege has also been poorly complied with—only 16% of the time. It states, simply, that rehire privileges should be carefully explained to terminees. Only SmithKline met this guideline in the latest report. Several of the other employers apparently have some type of policy on rehiring. However, a majority of the terminees from the firms stated that those privileges were not explained to them.

The severance pay standard has always been a tough one for employers to meet. It calls for a minimum of two weeks' pay per year of service. It has been complied with only 17% of the time. But in the latest report, three of the 10 companies involved—Gulf Research & Development, SmithKline, and Texaco—met the standard. Gulf's policy provides two weeks' pay per year of service, with a minimum of three months' pay and a maximum of one year. Terminees from Texaco confirmed that the company provided one half-month's pay per year of service. And the majority of terminees from SmithKline reported receiving two or more weeks' pay per year of service.

In the latest report, six of the 10 employers met the standard for advance notice—sharply higher than the average 38% compliance of the previous reports. This guideline calls for a minimum of four weeks of notice. In three cases in the latest report, the standard was exceeded. Terminees received up to 11 weeks' notice at Allied-Signal, up to six weeks at U.S. Steel, and up to 14 weeks at Penn Central.

Employer compliance with ACS guidelines

These employers provided information	Approximate number of terminees	Advance notice	Severance pay	Assistance	Pension vesting	Employee service	Protection plans	Rehire privileges
Allied-Signal Corp., Buffalo Research Lab (Buffalo, N.Y.)[a, b]	15	☐	▨	☐	☐	▨	▨	▨
Chevron Corp./Gulf Oil Corp., Gulf R&D Co. (Harmarville, Pa.)[b, c, d]	73	☐	☐	☐	☐	▨	▨	▨
Occidental Petroleum Corp., Cities Service Oil & Gas Corp. (Tulsa)[b, d, e]	11	☐	▨	☐	☐	▨	☐	▨
Occidental Petroleum Corp., Occidental Research Corp. (Irvine, Calif.)[a, d, e]	35	▨	▨	☐	☐	▨	▨	▨
Penn Central Corp., General Cable Corp. (Edison, N.J.)	3	☐	▨	☐	☐	■	▨	▨
Stauffer Chemical Co., Pelser Labs (Houston)[b, c, d, f]	3	▨	▨	▨	☐	■	▨	▨
Texaco Inc., Texaco Research Center (Beacon, N.Y.)[b, d]	20	☐	☐	☐	☐	■	☐	▨
U.S. Steel Corp. Technical Center (Monroeville, Pa.)[b, e]	19	☐	■	☐	☐	■	▨	▨
These employers provided no information; hence, all ratings based on terminee responses								
SmithKline Beckman Corp., SmithKline & French Labs (Philadelphia)	7	▨	☐	☐	■	■	☐	☐
Wright Chemical Corp., Subsidiary of Portals Holding Ltd. (Schiller Park, Ill.)	21	■	▨	■	☐	■	▨	▨

☐ Employer met guideline standard.

▨ Employer did not fully meet guideline standard.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than two weeks.
- Assistance—no assistance rendered.
- Severance pay—less than one week per year of service.
- Employee service—more than 40% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

a Rating on advance notice based on information from the terminees. b Rating on rehire privileges based on information from the terminees. c Rating on employee service based on information from the terminees. d Rating on protection plans based on information from the terminees. e Rating on severance pay based on information from the terminees. f Rating on assistance based on information from the terminees.

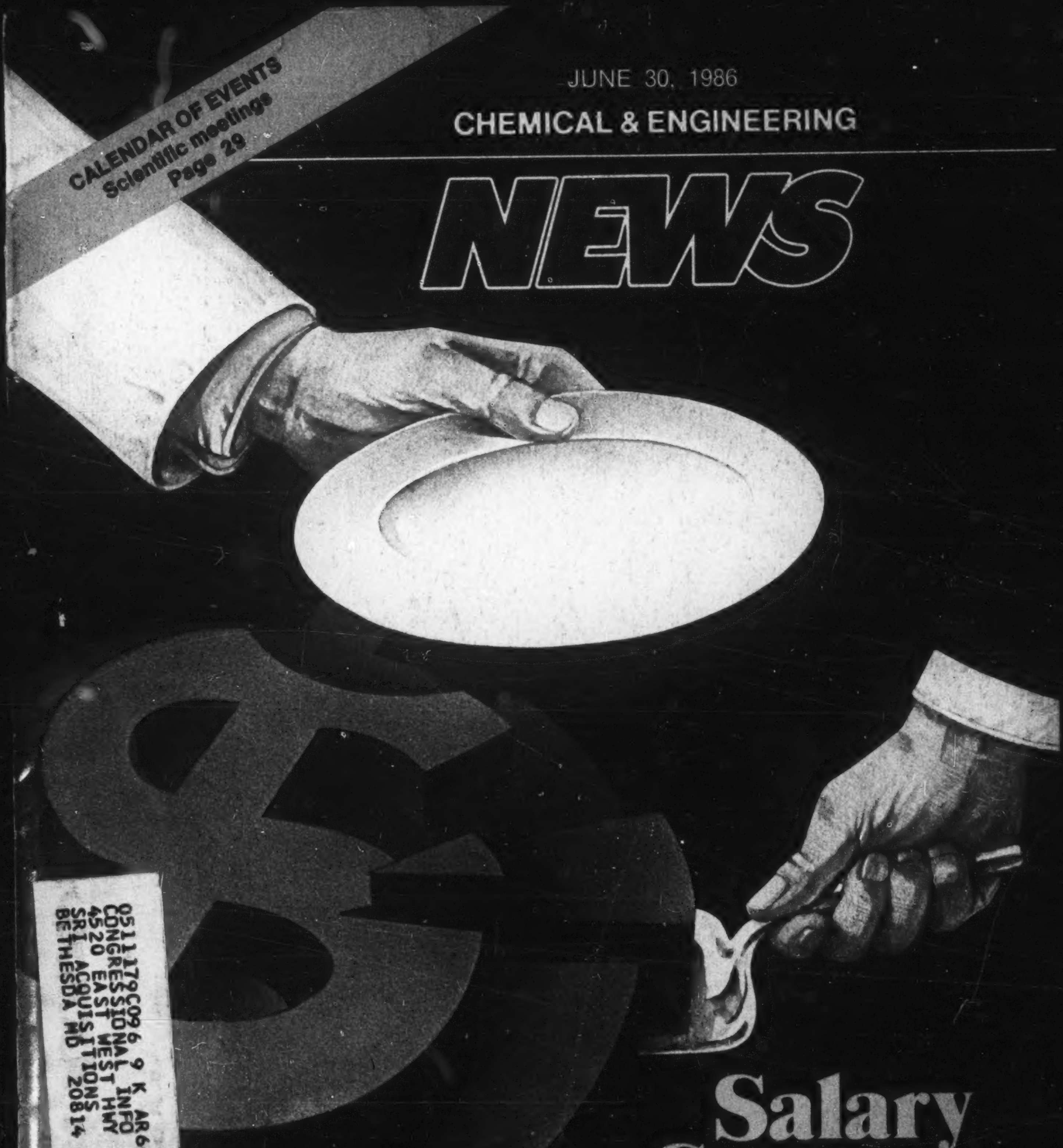
The standard for employee protection plans states that such plans should be extended beyond termination by a minimum of one month plus two weeks for each year of employee service. It has been complied with about half the time. But in the recent report, only three of 10 employers—Occidental Petroleum, Texaco, and SmithKline—complied.

The standard on assistance states that efforts should be made to place terminees in other positions within an organization, or terminees should be given help in finding jobs elsewhere. It has generally been well complied with—more than two thirds of the time. And according to CPR, eight of the 10 companies either met or came close to this standard.

The standard most frequently complied with—84% of the time—is the one calling for full pension vesting after 10 years of service. SmithKline was the only company to fail to meet it in the latest report. Terminees from SmithKline report that pension rights are fully vested only after 15 years of service. ☐

JUNE 30, 1986

CHEMICAL & ENGINEERING NEWS



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Chemists get slightly bigger slice

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CHEMICAL & ENGINEERING
NEWS

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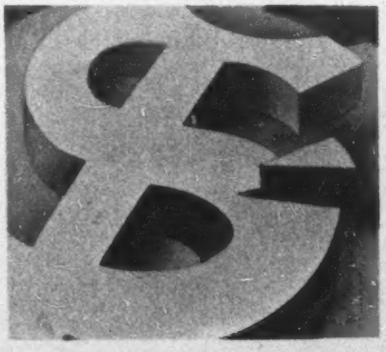


Salary Survey

Unemployment among chemists rose slightly last year but salaries made good gains, moving above cost-of-living increase. Page 23

New Era of Inherently Safe Nuclear Reactor Technology Nears

Chernobyl accident overshadows culmination of development work aimed at improving reactor safety and reliability

Joseph Haggin, C&EN Chicago

It is still too early to assess the ultimate impacts of the Soviet nuclear reactor failure at Chernobyl at the end of April. But one positive result has appeared. A renewed focus on nuclear reactor safety has highlighted more than a decade of largely unheralded work by U.S. and western nuclear engineers aimed at improving reactor safety and reliability.

That work intensified following the reactor incident in 1979 at Three Mile Island, near Harrisburg, Pa. Almost unnoticed, the U.S. since then has edged into a new era in reactor technology built around liquid-metal reactors (LMR), more-reliable pressurized-water reactors (PWR), improved fuels, and more-secure reprocessing and waste disposal.

For the nuclear community, the biggest disappointment during the period has been the demise of the Clinch River breeder project. The U.S. government's decision to halt funding on that project effectively handed the world's lead in breeder reactor technology to the French. If the U.S. now decides to get back into the breeder business, it may find itself in the position of having to buy its technology from French sources. That prospect goes down hard among the nuclear fraternity, but it may someday become necessary if the U.S. is to generate nuclear power economically.

About a dozen types of commercial nuclear power reactors are now operating in the world. The dominant type, a virtual standard, is the pressurized light-water-moderated and -cooled reactor, or PWR. More than half the world's known reactors are of that type. In the U.S., 62 of the 100 operational reactors are PWRs.

The principal builder of PWRs in the U.S. is Westinghouse, which has been in the business for more than 30 years. The changes that have taken place, particularly those concerning reactor safety, have not been revolutionary. Raymond George, Westinghouse's manager of plant marketing, says the technical changes made from time to time have been neither great nor frequent. PWR technology is now mature, and progress is measured in small, regular increments. However, Westinghouse has cooperative agreements with Japanese nuclear interests to develop advanced PWRs.

A strong influence on the technology has been the advanced pressurized water reactor (APWR) project, in which George formerly was engineering manager. The APWR program employed extensive simulation and "what if" incidents to simulate nuclear power-downs of every possible kind. A major result was a decision to separate control and safety functions in nuclear power operations.

The important distinction is that separating safety and control systems provides yet another level of redundancy above that prescribed by the Nuclear Regulatory Commission. Control systems involve the actual operating control of the reactor on a routine basis. Safety systems operate when abnormal conditions are encountered. The two systems are interconnected but separate.

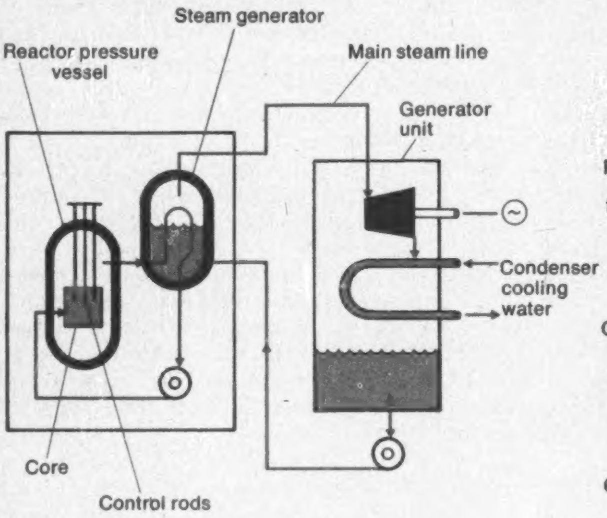
George believes that present PWRs are inherently safe, and the probability of a reactor shutdown caused by the most likely incidents is less than one in a million reactor years. It is possible to decrease the probability of shutdown by two more orders of magnitude, but many doubt that that would be of any actual benefit. George notes that the probability of shutdown has been decreased to roughly the level of a major meteoric impact on Earth's surface.

George believes that two principal incentives need to be considered concerning reactor safety. First is the obvious concern with public safety during a power shutdown. That is what most people fear when they address reactor safety. The only U.S. experience has been the Three Mile Island incident. TMI resulted in no hazard to the public because, George points out, the containment measures functioned as they were designed to function.

Much partisan publicity, pro and con, has been generated about TMI, but the reality is that no damage to the population resulted. The Chernobyl accident was, apparently, quite different. Although the causes and effects of the Chernobyl incident are still largely unknown, an obvious breach of integrity in reactor containment occurred. In fact, there apparently was no containment around the reactor.

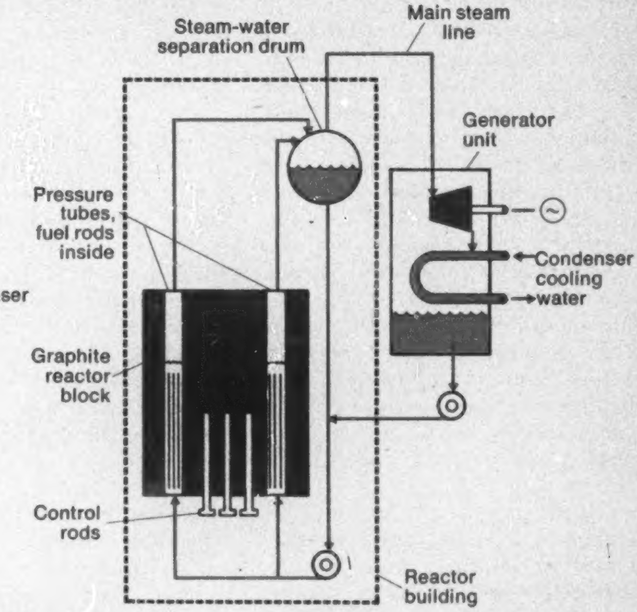
The second safety incentive, after concern for the public, is economic protection for the reactor owners. George suggests that people frequently fail to realize that the great investment in a nuclear power reactor is possibly one of the biggest single reasons for minimizing the effects of power-down. The owners have multibillion-dollar investments and can afford neither lengthy shut-

Typical U.S. pressurized-water reactor has containment . . .



Pressurized-water reactor uses fuel of slightly enriched uranium pellets encased in Zr-alloy fuel rods. Water is pumped through the core to remove fission heat. This water is pressurized to keep it liquid. Heat is transferred to intermediate steam generation system, which supplies steam to the generator. All units with a radioactive potential have protective containment structures

. . . graphite-moderated reactor at Chernobyl did not



RBMK-1000 reactor uses pellets of slightly enriched UO_2 sealed in Zr-alloy fuel rods. Bundles of rods are inserted directly into pressure tubes placed in the graphite moderator block. Water rising through the tubes is converted to steam by fission heat. Steam drives the turbine and is recycled. No containment structures were in use

Source: Atomic Industrial Forum

downs nor permanent closing before the productive lifetime of a unit has run out.

So considering the 35 years or so of relatively safe operation, PWR is the technology to beat in the present nuclear market. George is optimistic about the future of PWRs because they have a fine safety record, have proved to be effective, and will make it difficult for new types of reactors to compete. Most of the present concern about reactor safety, George believes, is misdirected. The record, he says, speaks for itself.

The decade following TMI happened to be the decade of consolidation for the computer. And it was inevitable that the computer would be employed to improve reactor safety.

Every utility company operating nuclear reactors has extensive computerization networks for control, warning, safety, and inventory control. Numerous research organizations and state governments duplicate those networks. Many believe that additional computer control will somehow raise reactor safety to new heights and that greater redundancy provided by additional computer systems is desirable in any event. It's debatable whether greater redundancy is needed, however.

One of the more extensive computerized monitoring systems is being developed at the University of Illinois in a program directed by Magdi Ragheb. He notes that the main causes of nuclear incidents are human error and equipment failure. Human operators can't hope to accommodate the data avalanche that ensues from even a slight upset in a nuclear plant. The answer, Ragheb suggests, is use of a supercomputer to process data, simulate the problem faster than it is actually happening, and forecast the result. That, in principle, would permit operator intervention, or automatic shutdown if necessary. The general idea has been applied in chemical process control for some time by a number of control laboratories, such as that at Purdue University under the direction of Theodore J. Williams.

If Ragheb's system is eventually developed, one of the first places it might be employed is in the State of Illinois Radiological Emergency Assessment Center. Illinois already has nine nuclear reactors in operation and four more under construction. Government monitoring of the reactors is being carried out by the center, and it would be easier, and probably more effective, if a system such as Ragheb's were used.

Meanwhile, some significant developments have emerged in reactor safety. They concern the design of new reactor types that are inherently safe; that employ new types of fuel that are easier and safer to make, use, and dispose of; and that are probably cheaper to build and operate. As a somewhat ironic coincidence, two major tests of those developments were completed successfully just before the accident at Chernobyl. Had that accident not occurred, the tests might well have gone unnoticed.

The development of liquid-metal reactors (LMRs) is being carried out under the auspices of the Department of Energy. That development is about all that survives from the Clinch River breeder project, and it contains the remnants of breeder development in the U.S. The main thrust of the project involves the integral fast reactor (IFR) idea. According to Charles E. Till, associate laboratory director for engineering research at Argonne National Laboratory, the main IFR features include liquid-sodium cooling, a pool reactor configuration, new metallic fuel, and an integral fuel cycle.

A basic idea of the design, Till explains, is to exploit the properties of liquid sodium as a coolant for the nuclear reactor. With sodium cooling, it is possible to operate the primary cooling system at atmospheric pressure. The boiling point of sodium is about 1600 °F. In a sodium-cooled reactor, coolant inlet temperatures are typically 650 °F and exit temperatures about 950 °F. That provides about a 500 °F temperature cushion and keeps temperature ranges within the limits of conventional containment materials.

Most of world's reactors are pressurized-water type

Reactor type	Operational	Building	Planned
Advanced gas-cooled, graphite-moderated	10	4	—
Boiling light-water-cooled and -moderated	79	15	3
Fast breeder	6	3	3
Gas-cooled, graphite-moderated	33	—	—
High-temperature, gas-cooled, graphite-moderated	3	—	—
Heavy-water-moderated, boiling light-water-cooled	1	1	—
Light-water-cooled, graphite-moderated	28	7	8
Pressurized heavy-water-moderated and -cooled	24	14	9
Pressurized light-water-moderated and -cooled	189	113	77
Steam-generating, heavy-water	1	—	—
Other types (unspecified)	—	—	16
TOTAL	374	157	116

Note: Types of nuclear power reactors as of Jan. 1, 1986. Source: International Atomic Energy Agency

Incorporating a coolant pool into the design configuration provides the safety inherent in a large thermal inertia, in that the pool can absorb reactor heat for a prolonged period. Even with total loss of coolant pumps, the natural convection in the pool is sufficient to transfer reactor heat to the coolant without damaging the core.

Nuclear designers have been trying to develop new metallic fuels for a long time. High thermal conductivity in the fuel itself permits low-temperature operation, while permitting the reactor to remain stable when power is reduced. That's another inherently safe condition.

Also, with metallic fuel, metallurgical fabrication procedures are simpler. According to Till, superior neutronics result, including the potential for excellent breeder capabilities. Generic metal fuels can now be designed with excellent radiation performance. For instance, a new fuel developed at Argonne's experimental breeder reactor-II (EBR-II) in Idaho has burnups exceeding 140,000 MW-days per ton of fuel.

The IFR, as envisioned at Argonne, also would include its own fuel fabrication and reprocessing facility. If that fuel cycle were used in a future commercial facility, the only time radioactive materials would need to enter or leave a reactor site would be when the reactor is built and when it is decommissioned. It is assumed that high enough breeder capacity would be used to eliminate the need for refueling from exterior sources. That would considerably improve operating safety by eliminating much of the over-the-road transportation otherwise needed for fuel and waste materials.

Till sees at least nine advantages of the IFR:

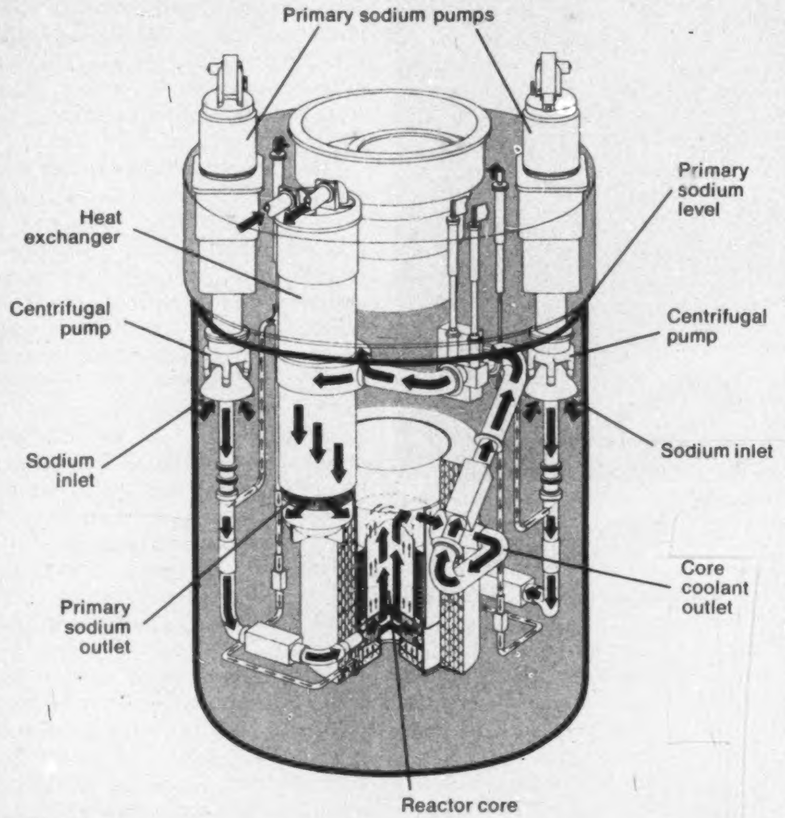
- Fuel performance is excellent. The metal fuels have burnup rates at least as high as those of conventional oxide fuels, and they have an appreciable neutronic advantage over the oxides.
- The metallic fuels are easy to make.
- Reprocessing techniques are simpler and cheaper than the conventional Purex process used for oxide fuels.
- Inherently greater safety results from using metallic fuels.
- IFR economics are expected to be in the LWR range and significantly better than for other LMR choices.
- The amount of radioactive waste is very small and easily managed.
- The need to transport plutonium-bearing fuel is eliminated.
- Because the fuel is made onsite, the chance for theft is greatly reduced.
- The system is well suited for designs above the 1000-MW(e) range. Or, because of its modular character, the IFR also can be adapted to small-unit power stations. Thus, plants can be dispersed—another intrinsically safe procedure.

In cooperation with General Electric and Rockwell International, two of the partners in DOE's LMR program, Till's group has estimated some of the economics of IFRs. The base design for estimating is a conceptual IFR that provides a generating capacity of 1200 to 1400 MW(e).

Preliminary cost estimates suggest that the initial capital investment would be about $57 million, or average fixed charges of about 0.5 mill per kWh. Operating and maintenance costs are about 1.2 mills per kWh, and assembly hardware costs are 1.3 mills per kWh. The fuel cycle can be started up with either plutonium or uranium-235. Although ^{235}U is more desirable, it is also more expensive.

One of the commercial developers in the IFR program is Atomics International, a unit of Rockwell International's Rocketdyne division. John McDonald, director of Atomics International, says that AI's version of the LMR is called the sodium advanced fast reactor (SAFR). It typifies the thrust toward more advanced innovative designs to create a less expensive, viable alternative to LWRs and to serve as a bridge to breeders that are expected to be needed in the future. It is, in effect,

Integral fast reactor has liquid sodium pool



A deep pool of thousands of gallons of liquid sodium accounts for much of the safety inherent in Argonne National Laboratory's integral fast reactor concept. The reactor core is submerged in the pool. Even without pumps to circulate sodium coolant, natural convection currents in the pool can keep the core from overheating

a "second generation" of nuclear reactor technology.

The SAFR plant employs a 350-MW(e) pool-type, liquid-metal (sodium) Power Pak as the basic module. The Power Pak is a standard, shop-fabricated unit that can be shipped to a plant site by barge. Modules can be used individually or in multiples to accommodate varying power demands. The 350-MW module was considered to be an optimum size by a number of utility companies and was also selected because it was about the largest unit that could be shipped by barge. It is also the largest module that could be built with a completely passive, reactor air cooling system for the removal of decay heat.

All the primary coolant in a SAFR is contained within the stainless steel reactor vessel, 39 feet in diameter and 48 feet high. A guard vessel around the reactor maintains a safe sodium level above the core. There are no penetrations in either the guard vessel or the reactor itself. All piping and instrument channels enter and exit through the top. Heat transfer is accomplished by new pump and piping designs.

The core of SAFR, McDonald says, can use either conventional mixed oxide (uranium/plutonium oxides) or the new metal fuels. Extensive experience has been gained with the oxide fuels, but the new fuels offer the advantages cited by Argonne's Till.

The fuel cycle for SAFR is envisioned at about four years, with 25% of the fuel being replaced each year. Although SAFR is not now designed for breeder operation, the reactor will accept breeder cores in the future. Spent fuel is allowed to decay for a year before being transferred to storage. If on-site fuel reprocessing is desired, it can be accommodated with little trouble. In addition to the reactor itself, containment consists of the guard vessel and an all-enclosing steel-lined concrete box.

As in the PWRs cited by Raymond George, reactor control systems have been decoupled from the safety systems. That design provides additional redundancy in safety systems and simplifies the construction of intermediate heat transfer systems. Public safety and investment protection are ensured by a variety of active and passive systems. The ultimate safety device is the design itself, which allows the reactor to be shut down to a totally passive condition without damage or hazard.

McDonald says that commercialization of the LMRs depends on completing final tests of reliability, financing, licensing, and the like. One plan proposes that a single module plant be built and operated by the late 1990s as a basis for obtaining a codified standard design approval from NRC.

The second commercial developer, General Electric, has designed a 135-MW(e) power reactor inherently safe module (PRISM) intended for factory assembly and transportation to an operating site by rail. PRISM is also a pool-type reactor that uses liquid sodium. The reactor will breed enough fuel to feed itself. The nuclear envelope is self-contained, and parts are designed for fabrication and assembly in a factory. The GE design calls for placing each reactor in an underground silo, with the steam generator in an adjacent silo. The rest of the plant is of conventional design.

A commercial PRISM plant would consist of three segments, each containing three PRISM modules. Each segment would be functionally independent but would be connected to a common steam drum. Heat from the reactor is transferred to a primary sodium loop and then to a secondary system before being used to produce steam.

The PRISM containment vessel is 19 feet in diameter and 64 feet high. It weighs 950 tons without fuel. The design accommodates Argonne's new fuel as well as conventional

Argonne National Laboratory engineers watch as coolant pumps are shut down during a test of the inherent safety of sodium-cooled nuclear reactors

oxide fuels. In addition to the primary containment of the reactor itself, the design includes a secondary containment system and an outer concrete barrier.

General Electric estimates that fabricating the first modules would take about three years, once the factory is built. Thereafter, a module might be built every three and a half months. Construction on-site would require another three years. Assuming the best design-fabrication-construction scenario, it might be possible to complete a 1200-MW(e) power station in 49 months by installing modules as they are made and bringing the plant on stream module by module. If the nuclear power business expands as is hoped, it would be possible to have modules "on the shelf" ready to meet orders.

U.S. has mostly pressurized-water reactors

U.S. reactor types	Number
Westinghouse Electric	
Pressurized-water reactors	40
General Electric	
Boiling-water reactors	35
Graphite reactor	1
Combustion Engineering	
Pressurized-water reactors	14
Babcock & Wilcox	
Pressurized-water reactors	8
General Atomic	
High-temperature gas-cooled reactor	1
Allis Chalmers	
Boiling-water reactor	1
TOTAL	100

Note: As of April 1, 1986, there were 100 operable reactors in the U.S., including 93 in commercial production, three with full-power licenses but not yet in full production, and four with low-power operating licenses. An additional 28 reactors have construction permits and two more are on order. **Source:** Atomic Industrial Forum

The ultimate test of an inherently safe design is to "pull the plug" and walk away from an operating unit. In effect, that's what Argonne did early in 1986. Between February and early April, a series of tests were conducted with EBR-II operating as an IFR. The tests left little doubt that an inherently safe design had, in fact, been developed.

According to Charles Till, on April 3, two potentially serious accident situations were initiated within hours of each other with the reactor operating at full power. In both cases, the plant shut itself down without any action by operators or the normal plant safety systems. Till maintains that no other type of reactor design could have survived accidents of that severity.

The first "accident" was a direct simulation of the classical loss of flow without scram—the emergency dropping of all control rods to instantaneously shut down the core. That is the ultimate control technique and effectively stops the core from functioning. Loss of flow without scram means that the rods were not dropped, and the core continued to function. With the plant operating at full power, protection systems were rendered inoperative, and power to the primary, secondary, and auxiliary pumps was instantaneously shut off. In effect, an instantaneous power blackout was created.

The reactor continued to run without forced cooling. Core temperatures rose, generating negative reactivity, which reduced the power level to zero. Although the coolant temperature rose briefly, it soon stabilized at a normal value. Till says the reactor would have remained in that condition indefinitely, if the test had not been terminated.

In a few hours, the second "accident" followed. It involved a total loss of heat sink without scram and with the reactor at full power. In many respects, that was similar to the accident at Three Mile Island. Again the results were about the same. The reactor simply shut itself off.

Those tests followed similar tests a few months earlier with the same results. Till emphasizes that EBR-II is a small reactor—20 MW(e). However, as noted by McDonald and others, it also approaches the size of the envisioned LMR modules, and it provides an active simulation of several of the most serious accidents that can be encountered on site. Simultaneous computer simulation verified the results of the EBR-II tests.

Following the Chernobyl accident, one of the most frequent charges by antinuclear advocates has been that all reactors pose inherent danger. They are radioactive, say the advocates, and therefore dangerous. The conflicting reports about nuclear safety written in the early 1970s are repeatedly brought up for reappraisal. It seems to have escaped notice that a lot has happened since the early 1970s and, in particular, since Three Mile Island. Safety, already high at the time of the Three Mile Island incident, has been greatly improved in the interim. Now a new generation of power reactors is about ready for commercial demonstration. Even an ardent foe of nuclear power should find the dramatic tests of EBR-II rather convincing. □

Unemployment Slightly Higher For Chemists in the Past Year

Salaries rise more than does the cost of living, with Ph.D. chemists faring best this year, ACS survey indicates

The U.S. chemical industry has taken unprecedented steps to streamline its operations and enhance its efficiency during the past year or so. Throughout the industry, companies large and small have shut down or sold off unproductive plants, dropped profitless or unpromising lines of business, pared their work staffs, and made other moves to prune operating costs. One result: Employment in the industry fell more than 20,000 (about 2%) between the end of 1984 and the end of last year, and has continued to decline since then.

This dramatic wave of corporate restructuring appears to have had relatively limited effect on the overall economic well-being of U.S. chemists, however. Unemployment has edged up a bit for chemists, to be sure, although it is no higher this year than it was a couple of years ago. Meanwhile, salaries earned by chemists, particularly those with a Ph.D. degree, have scored one of the best gains of recent years. In fact, after adjustment for inflation—which lately has been at its weakest since the early 1970s—salaries have made an especially strong showing during the past year.

As of last March, the unemployment rate for chemists who are members of the American Chemical Society was 1.7%, the latest ACS survey of the economic status of its members indicates. That is up from 1.4% a year earlier to the same level as in March 1984. As has been true in the past, unemployment among chemists is far lower than for the U.S. labor force as a whole—the overall rate of unemployment in the U.S. was 7.1% last March—and also is slightly less than unemployment among all professional workers, for whom the rate was 2.0% in March.

The small increase in unemployment this year is centered largely on industrial chemists. The joblessness rate for chemists whose current or most recent job is in private industry climbed to 2.2% this year, up from 1.5% in 1985 and 1.8% in 1984. And unemployment seems especially high for chemists working in production or marketing jobs. On the other hand, joblessness is lower this year for academic and government chemists than it was in 1985.

Unemployment, though generally low, is highest for chemists without a graduate degree

	Chemists									
		By sex		By highest degree			By minority status			
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority	Chemical engineers	All members[c]
Employed full time	93.7%	94.7%	88.7%	94.1%	94.7%	93.3%	91.2%	94.0%	93.5%	93.5%
Employed part time	1.6	0.9	4.7	1.4	2.1	1.4	1.8	1.6	1.8	1.6
Postdoctoral or fellowship	1.8	1.8	1.9	0.0	0.1	3.2	4.3	1.6	0.4	1.7
Unemployed										
Seeking employment	1.7	1.6	2.0	2.6	1.7	1.3	2.2	1.6	2.4	1.8
Not seeking employment	1.2	0.9	2.6	1.9	1.4	0.8	0.5	1.2	1.8	1.4

a As of March 1, 1986. b Black, Hispanic, American Indian, Alaskan native, Asian, Pacific Islander, or other. c Includes ACS members whose highest degree and present work are in neither chemistry nor chemical engineering. **Source:** ACS survey

Chemists with Ph.D.s win biggest salary increases in the past year

												Annual change	
$ Thousands	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985–86	1981–86	1976–86
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$33.0	$32.0	$30.9	$30.0	$28.5	$27.5	$25.0	$23.5	$22.0	$21.0	$19.8	3%	4%	5%
M.S.	37.9	36.0	34.0	33.0	31.6	30.0	26.0	25.0	24.0	22.0	20.5	5	5	6
Ph.D.	47.8	44.0	42.0	40.0	37.5	35.0	31.2	29.0	27.4	26.0	24.7	9	6	7
All chemists	42.5	40.0	38.0	36.0	34.7	32.0	28.9	na	na	na	na	6	6	na

a As of March 1, 1986. na = not available. **Source:** ACS survey

Salaries tend to increase most rapidly during the first 20 to 30 years of a chemist's career

Years since B.S. degree	Median salary ($ thousands)[a] 0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
NONACADEMIC CHEMISTS											
B.S.											
90%	$27.5	$30.0	$38.0	$47.0	$52.0	$55.2	$60.9	$64.8	$64.0	$73.0	$52.5
75%	24.0	27.0	33.5	40.0	45.0	50.0	50.2	54.0	55.0	57.0	43.0
50%	21.0	24.0	29.0	34.5	39.0	43.0	43.0	45.0	47.0	42.9	33.8
25%	18.8	20.6	25.0	28.0	32.0	36.0	35.2	36.2	39.0	34.0	26.0
10%	15.0	17.6	21.0	24.6	28.0	27.9	29.0	31.0	29.1	25.0	21.8
M.S.											
90%	—	32.2	40.0	47.0	55.0	61.0	64.7	67.8	68.8	82.5	60.0
75%	—	30.0	34.7	42.0	48.0	52.7	55.0	59.8	59.0	60.2	48.8
50%	—	27.0	30.5	35.8	40.0	42.0	46.3	50.0	50.0	49.5	39.0
25%	—	23.8	26.8	30.6	34.0	35.0	37.0	40.0	43.9	42.5	31.7
10%	—	22.0	24.0	26.9	30.0	29.6	27.2	32.6	34.0	29.5	26.8
Ph.D.											
90%	—	—	45.1	54.0	64.0	75.0	76.0	82.2	85.0	82.4	73.0
75%	—	—	42.0	48.9	55.7	62.6	65.0	69.6	73.3	71.8	60.0
50%	—	—	39.1	43.4	48.0	54.0	55.0	56.4	62.7	60.0	49.9
25%	—	—	36.9	39.6	42.3	45.6	47.1	48.0	52.0	51.0	42.0
10%	—	—	34.0	35.5	37.4	40.0	40.2	41.1	43.8	38.8	37.0

[a] As of March 1, 1986. **How to read this table:** Using, as an example, nonacademic B.S. chemists two to four years after having received their B.S. degree, 90% of these chemists have annual salaries of $30,000 or less, 75% have annual salaries of $27,000 or less, 50% have annual salaries of $24,000 or less, 25% have annual salaries of $20,600 or less, and 10% have annual salaries of $17,600 or less, as of March 1, 1986. **Source:** ACS survey

It is men, too, and largely those with no more than a bachelor's degree, who have borne this year's increase. The unemployment rate among women chemists, which typically is greater than that for men, is down to 2.0% from 2.4% in 1985. The rate for men, meanwhile, climbed to 1.6% this year from 1.2%. In recent past years, the rate for women chemists has run from 60 to 100% higher than that for men. This year, though, it is only 25% higher. And although unemployment is up only very slightly this year for chemists with a graduate degree, for those with just a B.S. the rate has jumped to 2.6% from 2.0% in 1985.

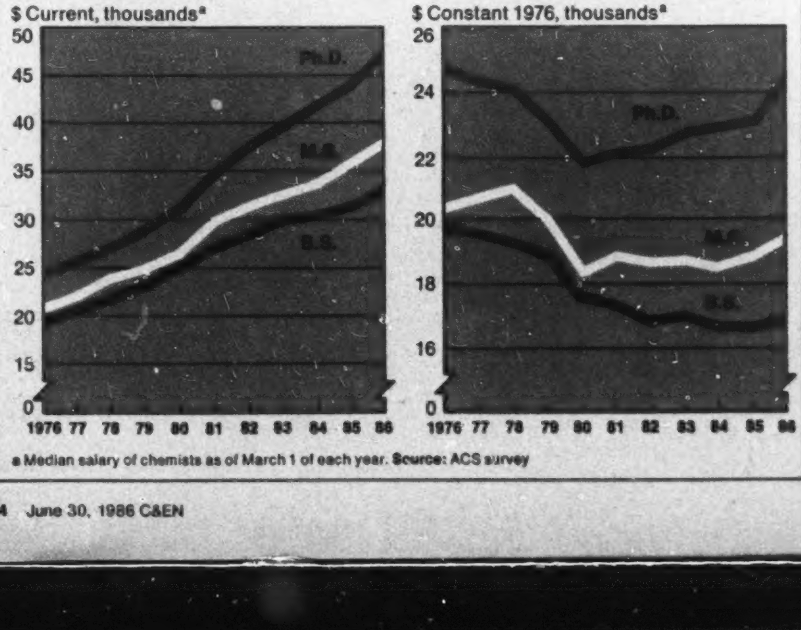
In one other way the pattern of unemployment is unusual this year. Generally in the recent past, unemployment has varied little with age; if anything, it has tended to be slightly higher for younger chemists, who presumably are more mobile. This year, however, the rate for chemists under 55 is 1.5%; that for chemists between the ages of 55 and 65 is 2.7%. This is consistent with information collected by the ACS Committee on Professional Relations, which indicates that recent large-scale terminations of industrial chemists have most affected older individuals (C&EN, June 23, page 72).

Results regarding salaries from the annual ACS survey, conducted by the ACS Office of Statistical Services earlier this year, present a brighter picture, especially for chemists with a Ph.D. The median annual salary for Ph.D. chemists increased 9% between March 1985 and March 1986, the biggest year-to-year improvement since 1981 and well above the average annual rate of increase during the past decade. (The median is the salary that is exceeded by 50% of the respondents to the ACS survey.) The increase of 3% this year for B.S. chemists and 5% for those with an M.S. degree is more in line with increases in salaries reported by such chemists for previous years. For several years now, salaries of B.S. chemists have been rising at a slower rate than for chemists with graduate degrees, and this year is no exception.

Year-to-year salary increases also

Graduate chemists' salaries have risen enough . . .

. . . to more than offset inflation in past few years



a Median salary of chemists as of March 1 of each year. **Source:** ACS survey

For academic chemists, teaching at a Ph.D.-granting institution earns a higher salary

Years since B.S. degree	Median salary ($ thousands)[a] 5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
PH.D. CHEMISTS EMPLOYED FULL TIME IN ACADEMIA									
Ph.D.-granting schools									
Professor	—	—	$53.0	$54.0	$53.8	$58.4	$62.2	$64.2	$57.4
Associate professor	—	$37.9	40.3	40.3	(42.2)	(39.6)	(49.5)	—	40.3
Assistant professor	$32.8	31.4	(33.5)	—	—	—	—	—	32.4
All ranks[b]	31.3	33.0	39.1	48.4	51.2	55.4	59.9	63.0	47.7
Non-Ph.D.-granting schools									
Professor	—	—	(38.7)	44.5	42.8	46.0	47.7	(51.3)	44.5
Associate professor	—	(31.6)	33.0	36.5	36.4	(42.4)	—	—	35.7
Assistant professor	26.9	27.5	26.7	(33.0)	—	—	—	—	28.1
All ranks[b]	26.9	27.6	32.7	39.1	40.9	45.2	47.1	44.0	39.1

a As of March 1, 1986. b Includes instructors, lecturers, research associates, and others not listed seperately. **Note:** Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution. **Source:** ACS survey

look favorable when compared with the rise in the cost of living. Because inflation has cooled off so much in recent months, the median annual salary for Ph.D. chemists in constant-dollar terms is 6% higher this year than in 1985. That's the best real annual salary increase for Ph.D.s in many years. It certainly is the largest increase since 1981, when the median salary for Ph.D.s began to rise faster than consumer prices following a long period during the late 1970s when salary increases fell behind the rate of inflation. In real terms, therefore, the median for Ph.D.s now is at about the same level as 10 years ago.

For M.S. chemists, this year's increase in median salary, adjusted for inflation, is 3%, the largest gain since 1981. For B.S. chemists, on the other hand, the increase this year is a mere 1%. Because the median salary for B.S. chemists has risen relatively slowly in the past few years, its level, compared with the cost of living, is much less favorable than that for chemists with a graduate degree. As a result, the median for B.S. chemists, in constant dollars, is 14% lower this year than it was 10 years ago.

As in the past, salaries earned by women chemists generally are below those earned by men. In part, this is because age and experience are important factors influencing salary levels, and women chemists as a group are younger and less experienced than men chemists as a group. Thus, nearly 60% of women chemists, but only 30% of men chemists, earned their baccalaureate degree less than 15 years ago.

Even so, when salaries are adjusted to make allowance for differences in length of experience, men maintain a distinct advantage—ranging from about 10 to 20%, depending on highest degree and type of employer. (In adjusting salaries for differences in experience, comparisons must be made between mean rather than median salaries.) The persistent gap between men's and women's salaries does not seem to have changed appreciably in the past few years, moreover. In 1982, for instance, the adjusted mean salary for women chemists with a Ph.D. and working in industry was 96% that for their male colleagues; this year and last, the mean salary for similar women was 89% that for the men. Similarly, for women with a B.S. and working in industry, the adjusted mean salary was 88% that for men in 1982 and 85% that for men this year.

The spread between men's and women's salaries generally is narrow, nevertheless, for chemists who have entered the profession in the past 10 years or so. In fact, this year the median salary of women with a B.S. and working in industry who received their degree less than five years ago actually is higher than that for similar men. But in the upper experience brackets, men hold a strong advantage. The median salary for men in industry with a B.S. obtained 15 to 19 years ago, for example, is about 30% higher than that for women of similar character.

The influence of length of work

Women's salaries overall trail those for men more than 10%

Mean salary, $ thousands[a]	B.S. All chemists	B.S. Men	B.S. Women	B.S. Women as % of men	M.S. All chemists	M.S. Men	M.S. Women	M.S. Women as % of men	Ph.D. All chemists	Ph.D. Men	Ph.D. Women	Ph.D. Women as % of men
EMPLOYER												
Private industry	$36.6	$38.6	$32.9	85%	$42.1	$43.9	$36.7	84%	$53.0	$53.8	$47.8	89%
Academic	—	—	—	—	31.8	33.4	29.5	88	44.7	45.6	39.7	87
Government	33.6	35.2	29.6	84	37.4	38.0	34.6	91	48.0	49.1	40.5	82
Other	31.5	32.9	28.5	87	34.0	36.2	31.7	88	50.8	52.9	44.0	83

a As of March 1, 1986; to facilitate comparison, salaries are adjusted for differences in the average experience for each group. **Source:** ACS survey

For industrial chemists, a job in management brings top pay

Years since B.S. degree		Median salary ($ thousands)[a]										
		0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY												
Sex												
Men	B.S.	$22.0	$24.0	$30.0	$36.0	$40.9	$44.0	$45.0	$46.0	$48.2	$44.8	$37.0
	M.S.	—	(27.1)	32.0	36.6	41.0	45.0	49.7	50.0	51.5	52.5	42.0
	Ph.D.	—	—	39.6	44.0	49.6	57.0	58.5	60.0	64.0	64.0	50.6
Women	B.S.	23.2	25.0	28.0	31.2	31.1	(43.0)	(29.0)	(36.2)	(36.0)	(32.5)	27.5
	M.S.	—	(27.6)	30.0	34.2	40.0	38.0	(37.8)	(33.0)	—	—	33.5
	Ph.D.	—	—	39.3	43.6	46.1	46.0	(49.2)	(49.9)	—	—	42.3
Work function												
General management	B.S.	—	(27.8)	32.5	45.0	41.0	(45.6)	(57.0)	(52.0)	45.0	(50.0)	40.5
	M.S.	—	—	(36.0)	(49.5)	44.6	(51.2)	(57.0)	(51.5)	(56.0)	—	48.5
	Ph.D.	—	—	—	(46.7)	(61.5)	64.5	58.4	(65.5)	(73.2)	—	62.2
R&D management	B.S.	—	—	37.2	38.5	46.5	(50.0)	(41.5)	52.0	50.7	(51.5)	47.0
	M.S.	—	—	—	40.0	50.0	54.5	55.0	(60.5)	(61.5)	(55.0)	51.8
	Ph.D.	—	—	(43.0)	51.0	59.4	63.0	65.0	71.0	78.0	69.0	63.0
Basic research	B.S.	(22.7)	24.3	28.3	27.8	(41.2)	—	—	—	—	—	28.0
	M.S.	—	(27.1)	31.8	34.0	(40.2)	(35.8)	—	—	—	—	34.7
	Ph.D.	—	—	40.0	44.0	49.3	53.8	59.5	62.0	64.0	56.8	46.1
Applied research[b]	B.S.	22.5	24.6	29.6	34.2	37.2	41.0	43.0	46.0	48.0	(49.6)	32.0
	M.S.	—	(27.6)	31.0	36.0	39.0	39.6	47.0	46.1	51.5	(44.1)	37.0
	Ph.D.	—	—	39.5	42.0	46.6	51.0	55.0	53.8	52.8	60.0	46.2
Production[c]	B.S.	(20.2)	24.0	28.0	32.5	32.5	37.5	(39.5)	36.0	(40.0)	—	30.0
	M.S.	—	—	29.3	35.0	39.3	38.0	(37.0)	(41.5)	(48.5)	—	36.0
	Ph.D.	—	—	—	(45.0)	45.0	45.0	(47.0)	(54.2)	(52.0)	(52.8)	46.2
Marketing[d]	B.S.	—	(24.5)	29.2	40.4	48.0	(50.0)	(42.0)	(45.0)	50.8	(43.0)	42.0
	M.S.	—	—	32.0	37.2	(46.0)	(45.5)	—	(59.2)	(50.0)	—	45.0
	Ph.D.	—	—	—	(45.0)	(53.0)	55.6	(51.0)	(64.0)	—	—	53.0
Work specialty												
Analytical chemistry	B.S.	20.6	25.0	29.0	33.0	36.0	40.0	39.0	40.0	44.0	(40.0)	32.0
	M.S.	—	(26.4)	29.6	34.0	40.0	42.0	40.4	44.8	51.9	(41.2)	38.0
	Ph.D.	—	—	40.0	44.0	45.0	53.2	50.4	54.5	59.0	(65.0)	45.0
Agricultural and food chemistry	B.S.	—	—	(29.0)	(35.0)	(35.4)	—	—	—	—	—	39.0
	M.S.	—	—	(30.0)	(37.4)	(33.0)	(48.0)	—	—	—	—	36.8
	Ph.D.	—	—	(37.5)	43.5	50.2	53.0	(58.2)	(62.0)	—	—	50.3
Biochemistry and biotechnology	B.S.	—	(24.8)	(26.8)	(38.2)	—	—	—	—	—	—	28.0
	M.S.	—	—	(29.2)	34.8	(42.4)	—	—	—	—	—	35.5
	Ph.D.	—	—	38.9	43.0	50.0	48.4	54.8	(74.0)	(61.0)	—	47.1
Environmental chemistry	B.S.	—	22.5	33.0	38.2	(41.0)	(42.0)	(45.5)	(47.5)	—	(39.2)	35.0
	M.S.	—	—	(31.0)	37.2	(41.0)	(56.5)	—	—	—	—	38.0
	Ph.D.	—	—	—	(41.0)	(45.3)	(59.6)	(61.2)	(55.6)	(68.0)	—	52.9
Inorganic chemistry	B.S.	—	—	(31.0)	—	—	—	—	(59.5)	(42.2)	—	36.8
	M.S.	—	—	—	—	—	—	—	—	—	—	54.0
	Ph.D.	—	—	40.1	42.0	48.0	57.5	—	(56.0)	(64.0)	(51.2)	47.5
Medicinal and pharmaceutical chemistry	B.S.	—	24.0	27.4	(28.0)	(49.0)	—	—	(36.2)	(47.0)	—	31.4
	M.S.	—	—	(32.5)	(36.0)	40.5	(41.8)	—	(50.8)	—	—	37.5
	Ph.D.	—	—	40.0	43.0	48.8	57.7	55.9	54.2	66.0	70.7	50.0
Organic chemistry	B.S.	(22.8)	25.0	29.0	35.5	41.5	(45.6)	42.5	45.0	48.0	—	36.8
	M.S.	—	—	30.0	34.8	40.0	(39.0)	(46.0)	(55.0)	(55.4)	(55.0)	38.8
	Ph.D.	—	—	39.0	43.0	49.2	59.5	59.5	59.0	60.8	56.8	49.6
Physical chemistry	B.S.	—	(26.5)	(32.0)	—	—	—	—	—	—	—	38.0
	M.S.	—	—	(32.0)	(35.6)	—	—	—	—	—	—	35.6
	Ph.D.	—	—	(40.0)	(48.0)	51.2	57.0	70.0	61.3	76.0	(61.5)	55.0
Polymer chemistry	B.S.	(24.1)	24.0	32.0	36.0	41.0	47.0	(47.4)	49.5	50.0	(51.0)	36.6
	M.S.	—	—	35.0	39.8	44.0	50.8	50.0	52.3	(61.0)	—	42.6
	Ph.D.	—	—	39.4	44.1	49.9	56.1	59.3	62.3	62.5	55.8	51.8

a As of March 1, 1986. b Includes development. c Includes quality control. d Includes purchasing, technical service, and economic evaluation. **Note:** Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution. **Source:** ACS survey

Unemployment edges up a bit this year for chemists

Employment status[a]	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Employed full time	94.8%	95.2%	93.7%	93.5%	94.9%	95.6%	95.9%	95.0%	95.7%	95.4%	94.7%
Employed part time	1.5	1.5	1.7	1.7	1.4	1.1	1.0	2.0	1.0	1.1	1.3
Postdoctoral or fellowship	2.0	1.9	2.9	2.6	2.2	2.2	2.2	1.9	1.9	2.1	2.2
Unemployed	1.7	1.4	1.7	2.2	1.5	1.1	0.9	1.1	1.4	1.5	1.9

a As of March 1, 1986; excludes chemists who are not employed but not seeking employment. Source: ACS survey

Pay is highest for industrial chemists working for oil firms

	% of industrial chemists				Mean salary ($ thousands)[a]		
Industry	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Pharmaceuticals[b]	18%	17%	19%	18%	$35.9	$38.7	$52.2
Chemicals[c]	16	13	15	19	36.9	40.2	50.2
Agricultural chemicals	7	5	6	9	36.5	40.8	50.0
Petroleum and natural gas	6	5	5	8	42.3	46.7	56.7
Coatings	6	8	6	4	35.8	42.6	51.6
Electronics	5	6	5	5	35.3	40.5	52.8
Biochemicals and biotechnology	4	3	3	5	40.5	33.0	47.5
Food	4	5	5	3	37.5	36.6	43.5
Metals and minerals	3	4	3	2	33.7	40.8	43.9
Soaps and detergents	3	3	3	2	37.2	59.7	48.7
Rubber	2	3	3	2	34.6	41.1	48.6
Paper	2	2	1	2	38.2	42.2	52.1
Other manufacturing	17	17	17	16	37.1	40.7	50.6
Nonmanufacturing	7	10	9	5	34.1	40.9	50.7

a As of March 1, 1986; to facilitate comparison, mean salaries are adjusted for differences in the average experience for each group. b Includes personal care products. c Excludes chemical sectors listed seperately. Source: ACS survey

Joblessness is greatest among industrial chemists

	% of chemists in category	% unemployed[a]
MOST RECENT EMPLOYER		
Industry	62%	2.2%
Academic	22	0.8
Government	10	0.3
Other	6	1.7
MOST RECENT WORK FUNCTION		
R&D	44%	1.5%
R&D management	12	1.7
Teaching	11	0.9
General management	8	2.2
Production[b]	7	3.5
Marketing[c]	5	3.5
Other	12	1.6
MOST RECENT WORK SPECIALTY		
Analytical	20%	1.6%
Organic	14	1.7
Polymer	12	1.9
Biochemistry[d]	9	1.4
Physical[e]	8	1.6
Medicinal[f]	7	1.8
Environmental	6	1.8
Inorganic	5	2.2
Agricultural[g]	3	0.3
Other	9	1.9
Nonchemistry	7	1.9

a As of March 1, 1986; excludes chemists who are not employed but not seeking employment. b Includes quality control. c Includes purchasing, technical service, and economic evaluation. d Includes biotechnology. e Includes theoretical chemistry. f Includes pharmaceutical and clinical chemistry. g Includes food chemistry. Source: ACS survey

experience on salary levels is greatest during the first 20 years or so after entering the profession. Thus, the median salary of a B.S. chemist with a nonacademic job who graduated 20 to 24 years ago is double that of the individual who has graduated in just the past year. But the median rises only another 10% for those with an additional 15 years of experience.

Sex and experience are not the only determinants of salary, to be sure. Where a chemist works is another factor. Salaries tend to be highest for those employed in industry, lowest for those who teach. For academicians, moreover, chemists are likely to earn more if they teach at a Ph.D.-granting school.

Among industrial chemists, the median salary has long been highest for those working for petroleum companies, whereas the lowest medians are in industries that employ relatively few chemists, such as metals, rubber, and food. And for industrial chemists, too, as would be expected, managerial positions are the most remunerative, although basic research and marketing also seem to pay well if allowance is made for length of experience.

In any event, most chemists seem satisfied with how they earn their living. Asked if they had it to do over again, would they take the same job that they now have, 77% of the respondents to the ACS survey agree that they would; only 15% would not (8% have no opinion). Satisfaction apparently is strongest among chemists working at universities and colleges; 81% would take the same job, only 13% would not.

A similar finding is that 16% of the survey respondents who are now employed full-time claim to be actively seeking a new job.

The data reported here on employment and salaries for the chemical profession are based on nearly 11,000 responses to a mail survey of a random sample of ACS members that was made by the ACS Office of Statistical Services last March. The survey was limited to members who reside in the U.S., are under age 70, and are neither emeritus nor student members.

A full report on results of the annual ACS survey for 1986, containing more detail, will be published in July by the Office of Statistical Services. The report, "Salaries 1986," can be purchased from Distribution, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. The price of this year's report is $99 per copy. □

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JULY 7, 1986

CHEMICAL & ENGINEERING NEWS

Times are better for major thermoplastics
A Key Polymers Review Page 12

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Volume 64, Number 27
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CHEMICAL & ENGINEERING NEWS

JULY 7, 1986

News of the Week

- **Industry analysts expect 1986 chemical firms' earnings to increase strongly over 1985 figures.** **Page 6**
- **Senate committee approves bill changing current product liability laws.** **Page 7**
- **Two science magazines have been sold recently—AAAS's *Science 86* to Time Inc., and *Scientific American*.** **Page 7**
- **Its Command herbicide is safe, FMC says, even though it bleaches vegetation near its target plants, soybeans.** **Page 7**
- **Nova Pharmaceutical and Celanese joint venture, Novacel, will develop controlled-release drug-delivery systems.** **Page 8**
- **Advances in dental care include technique for removing tooth decay, new compound to fill cavities in areas where appearance is important.** **Page 8**

Cover: Photovoltaic panels at Arco Solar's Carrisa Plains project in San Luis Obispo County, California. The electrical output is sold to Pacific Gas & Electric Co.

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Business

Thermoplastics production records will be set in 1986 and the growth in output is likely to continue in 1987. **Page 12**

Mattson Instruments, founded in 1983, has 20% of FTIR market and continues to move aggressively with product development. **Page 21**

Government

Science adviser nominee William R. Graham will contend with issues ranging from scientific manpower to the space program. **Page 23**

Science

Yale chemists achieve total synthesis of *N*-acetylneuraminic acid, one of a family of acids that have potent biological activity. **Page 28**

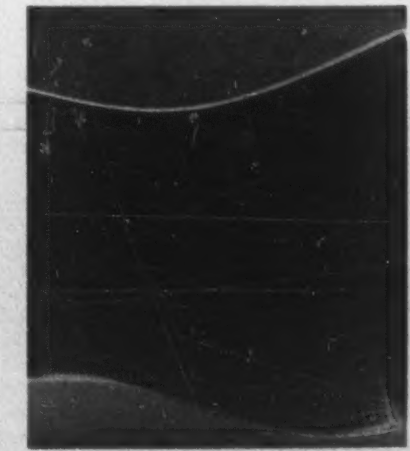
New protein that regulates secretion of follicle-stimulating hormone in mammalian ovary discovered by two groups independently. **Page 30**

Education

Top liberal arts colleges must invest $1 billion in basic science over next decade, according to Oberlin College study. **Page 31**

Books

"Inside the Technical Consulting Business" is well organized, offers comprehensive coverage of the business aspects. **Page 49**



Special Report

Photovoltaic cells, which may eventually replace conventional fuels for generating electricity in large-scale power plants, are out of the lab and into the marketplace. **Page 34**

Thermoplastics Head for Production Records in 1986

Growth in output of five major thermoplastics likely will continue into 1987; profit margins have greatly improved so far this year

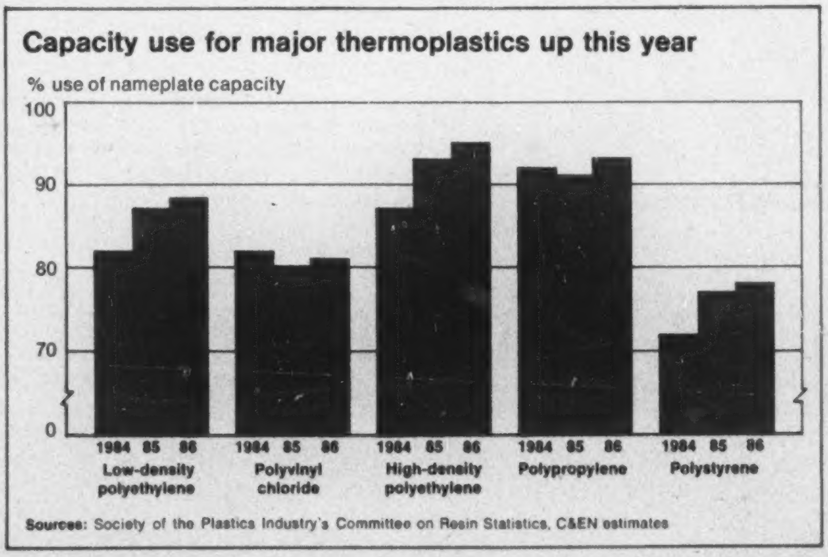
Bruce F. Greek, C&EN Houston

Producers of thermoplastics are on a roll. The five largest-volume thermoplastics will each set new production highs in 1986. Selling prices for these resins are significantly below levels that producers would like, but margins have greatly improved so far this year because monomer costs have rapidly declined. And producers are finding greater profitability in thermoplastics through higher operating rates and process improvements at plants.

Growth in thermoplastics output likely will continue into 1987 at nearly the current pace, barring a major economic downturn. The present major uses of thermoplastics—packaging, building and construction, and consumer products—are expected to require more of these resins as well as other plastics, as their markets expand and they gain market share at the expense of older products such as paper and glass. This market growth is resulting in production growth rates this year of 3%, for example, for polystyrene and 6% for polypropylene.

Key Polymers

Growth in production could be even greater except that competition among thermoplastics is becoming more severe and imports continue to rise. For example, some film made of the three polyolefins and, to a lesser extent, polyvinyl chloride, is going into similar end uses. Imports of low-density polyethylene and PVC are still rising and could reach 10% of consumption before the end of this decade.


Capacity use for major thermoplastics up this year

Sources: Society of the Plastics Industry's Committee on Resin Statistics, C&EN estimates

Forecasts for future growth again include conditions relating to capacity availability for some of the thermoplastics. Capacity to make polypropylene and high-density polyethylene will be pushed in 1986 to meet demand expected in both U.S. and export markets. Several expansions of capacity are under way, and others are rumored. Debottlenecking, conversion of some linear low-density polyethylene capacity to HDPE, and diversion of exports are other possibilities for increasing output. Industry sources expect a little of all of these methods to be used in 1987, just as they are this year.

The decline in overcapacity for thermoplastics isn't expected to do much for prices and margins. As prices for crude oil and gas liquids level off, and monomer prices do likewise, margins also are receding as producers cut prices to maintain their market share. If hydrocarbon feedstock prices rise and fall because of political pressures, then overall profitability in selling thermoplastics again will sag and supply-demand situations will have lesser importance.

Besides changes in plant capacities, demand, and prices, thermoplastics also have had changes in ownership. So far, most of them have been for polystyrene and PVC, which are produced by a larger number of companies than the other resins. Shifts in ownership have occurred for other polyolefin plants, and more may be in the offing because of changes wrought by the decline in crude oil and gas prices. However, such changes are expected to peak this year.

For some details of the near-term outlook for the five largest-volume thermoplastics, please see the following pages.

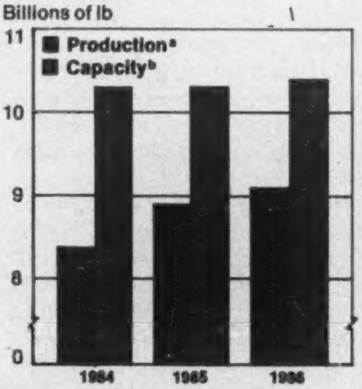
Key Polymers

$$\sim\!\!\left[\text{CH}_2-\text{CH}_2\right]_n\!\!\sim$$

Low-density polyethylene

- ***Production rising***
- ***Capacity steady***
- ***Prices firming***

PRODUCTION/CAPACITY



a Conventional and linear low-density polyethylene.
b First quarter; adjusted to account for dual capacities to make both forms.

MAJOR PRODUCERS

Chevron, Dow Chemical, Exxon, Enron (Norchem), Union Carbide

HOW MADE

Polymerization of ethylene (with comonomers as needed) at high and low pressures aided by catalysts and reaction initiators

MAJOR FABRICATED FORMS

Film (mainly for packaging) 60%, extrusion coatings 10%, injection-molded items 10%, wire and cable coverings 5%

FOREIGN TRADE

Exports—declining to about 1 billion lb, imports—rising to more than 500 million lb

PRICE

36 to 40 cents per lb, depending on grade

Low-density polyethylene output continues to grow, fueled by constantly expanding demand for plastic bags. This year, production probably will top 9.1 billion lb and possibly be more than 9.2 billion lb. Through conversion to bags, LDPE (produced in greater volume than any other plastic resin) obviously dominates the plastic film business, although other resins are making inroads.

Of LDPE production forecast for this year, more than two thirds will be made into film or be exported. At about 1 billion lb, exports of LDPE will rank a distant second as an outlet. A large number of other uses have been developed for LDPE during nearly 40 years of its commercial success in the U.S. Extrusion coatings, injection-molded items, and wire and cable coverings are among those uses but are small in proportion to use in film.

Growth in LDPE output in 1986 will range from 250 million to 300 million lb, which could turn out to be less than the volume gain expected for high-density polyethylene this year. The LDPE growth in 1986 will add about 3% to the 8.89 billion lb produced in 1985, according to the Committee on Resin Statistics of the Society of the Plastics Industry.

Capacity to make LDPE has not been a problem in recent years. In the first quarter of 1986, total capacity dedicated to making all forms of LDPE (including linear low-density polyethylene) was 10.4 billion lb. Some HDPE capacity possibly can be shifted to provide additional capacity. More likely, however, would be a shifting of LLDPE capacity to make HDPE, because demand for HDPE remains so strong. But probably no more than 500 million lb of LLDPE capacity would be shifted to HDPE, according to industry sources. Estimates of LLDPE capacity vary, but most sources put the practical total at about 3 billion lb, including 100 to 200 million lb normally included in HDPE capacity.

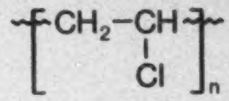
Consequently, if production of all forms of LDPE totals 9.1 billion lb in 1986 and nameplate capacity is 10.4 billion lb, then the operating rate will be merely 88%. But if 0.5 billion lb of capacity that produces mostly HDPE are excluded, then the operating rate rises to more than 90% of the reduced nameplate capacity.

Nevertheless, there is overcapacity for LDPE, keeping pressure on selling prices. Prices for major-volume grades range from 27 to 29 cents a lb, which is typically a third off list prices. The overcapacity also hinders efforts to raise prices, even as ethylene prices are pushed higher. The overcapacity won't end soon, because new capacity has been announced with on-stream dates for 1987 and because technological advances are debottlenecking existing plants more rapidly than would otherwise be the case.

The pressure exerted by converters of polyethylene film long ago has led major producers such as Dow Chemical, Mobil, and Union Carbide to enter the consumer market by selling various kinds and sizes of bags and films. Their marketing costs are high, but demand continues to grow, providing a steady outlet, and allowing them to have considerable economies from a more-even operation of monomer and polymer plants.

Several other fabricated forms of LDPE are growing well but from small bases. Of the smaller volume uses, extrusion coatings and injection molding have shown gains this year. The major part of extrusion coating uses is in making 1-qt milk cartons and other food containers.

Exports of LDPE could decline, especially as the various new LLDPE plants start up in various parts of the world. So far, exports appear to be down about 10% this year, or at a 100 million to 150 million lb annual rate. The decline in exports, which must be absorbed by the domestic market, could be the major reason that LDPE is growing at only about 3% in 1986.

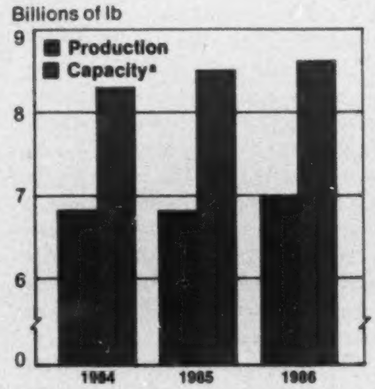


$$\left[-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}- \right]_n$$

Polyvinyl chloride

- ***Production up again***
- ***Capacity up a bit***
- ***Prices leveling***

PRODUCTION/CAPACITY



a First quarter.

MAJOR PRODUCERS

Formosa Plastics, Georgia Gulf, B. F. Goodrich Chemical, Occidental Chemical, Shintech

HOW MADE

Polymerization of vinyl chloride (sometimes with comonomers) initiated by free radicals

MAJOR FABRICATED FORMS

Pipe 45%, other extrusions 25%, calendered items 10%, molded items 5%

FOREIGN TRADE

Exports—holding at about 300 million lb, imports—rising to possibly more than 300 million lb

PRICE

37 to 50 cents per lb, depending on grade

Polyvinyl chloride output will increase in 1986 after stagnating for two years in the wake of a major production jump in 1983. Output in 1986 will top 7 billion lb, after holding at just below 6.8 billion lb in 1984 and 1985. This year's growth stems mostly from increased consumption of PVC in its major markets, particularly pipe and fittings and other construction components.

The increase in production of PVC expected during 1986 could be as much as 300 million lb but likely will be closer to 250 million lb. That increase of about 4% is small for a commodity resin of this size but for many organic chemicals would be large. Because imports of a host of different consumer products made from PVC hold down fabrication in the U.S., output likely will not exceed 7.1 billion lb.

As 1986 began, PVC capacity totaled 8.6 billion lb. Because of both debottlenecking and actual plant additions, capacity has been increasing. However, no major additions to capacity are expected this year.

Capacity utilization will not change much because the expansions during the past two years have been offset by increased output. Should production in 1986 slightly exceed 7 billion lb, the operating rate will reach 81% of estimated nameplate capacity.

Capacity ownership has been changing as capacity has increased. The largest recent shift in ownership occurred when Occidental Chemical bought Tenneco Chemical's PVC operations, a transaction involving some 700 million lb of annual capacity and completed during the second quarter.

It is debatable whether new ownership for a sizable portion of PVC capacity will improve profitability in making the resin. Efforts have been under way to restore selling prices to the 30 to 33 cent-per-lb range for most large-volume grades of PVC, up 2 to 3 cents a lb from levels reached during May. Whether the June prices will hold depends on what happens to ethylene during the third quarter and to previously announced price increases for chlorine, which accounts for more than half of the weight of the monomer.

Some of the price increases of PVC likely will result from monomer price increases passed along. Vinyl chloride producers have had some mechanical problems that have cut output periodically during the second quarter. Those problems, plus strong exports of both vinyl chloride and its precursor, ethylene dichloride, may have reduced polymer supply at a time when demand was strong, especially for pipe-grade resins.

The net of exports of vinyl chloride over imports for the first four months of 1986 was more than 420 million lb. Production during the same period is estimated at about 2.7 billion lb, suggesting that net exports account for more than 15% of production. With the production problems and high exports, vinyl chloride producers may be able to pass on their cost increases. PVC producers then would be forced to do the same. That could cause most of the newly announced price increases to hold for part of the third quarter, even while production declines at the end of the major demand cycle for pipe-grade resins.

PVC prices hinge on pipe-grade resins because those resins account for such a large share, nearly 45%, of U.S. consumption of the polymer. Large additional quantities of PVC go into fittings and other components used with pipe and tubing. Use of PVC pipe has been strong, causing inventories to be drawn down this spring.

The negative side of the PVC outlook involves the large exports of monomer. Much exported vinyl chloride returns to the U.S. in the form of finished nondurable goods, such as luggage, shoes, and other consumer products made of PVC. Such product imports are forecast to continue to rise, reducing U.S. consumer consumption of PVC while industrial uses keep growing.

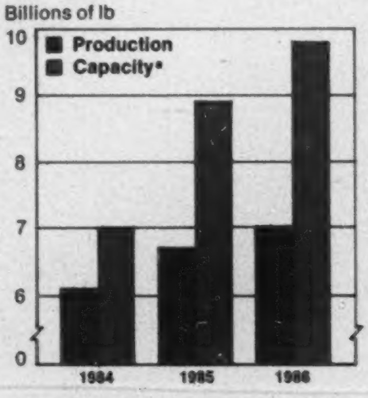
Key Polymers

$-\!\left[CH_2-CH_2 \right]\!-_n$

High-density polyethylene

- ***Production up well***
- ***Capacity up a bit***
- ***Prices holding***

PRODUCTION/CAPACITY



a First quarter; includes capacity capable of making either high-density or linear low-density polyethylene.

MAJOR PRODUCERS

Du Pont, Phillips, Soltex, Union Carbide, U.S.I.

HOW MADE

Polymerization of ethylene at low pressures aided by metallic salts and alkyls

MAJOR FABRICATED FORMS

Blow-molded items (mainly containers) 40%, injection-molded items 25%, film and sheet 10%, pipe and conduit 10%

FOREIGN TRADE

Exports—holding at about 800 million lb, imports—small, less than 50 million lb

PRICE

43 to 50 cents per lb, depending on grade

High-density polyethylene output will increase again this year because demand by most major-volume end uses as well as exports is rising. Smaller-volume uses—film, for example—also are growing strongly, spurred by product development leading to the capture of markets previously held by other materials.

The gain in HDPE production in 1986, however, will drop to half 1985's gain, according to most current forecasts. Production likely will top 7 billion lb for the first time, up more than 300 million lb, or 5%, from last year's 6.67 billion lb estimated by the Committee on Resin Statistics of the Society of the Plastics Industry. Output in 1985 was up about 600 million lb over 1984, the gain resulting from substitution of HDPE for other materials used in packaging and many other end uses.

Apparently capacity is sufficient for the HDPE production forecast for 1986. Because several producers have the capability to switch between linear low-density polyethylene and HDPE, estimates of actual capacity range from about 7.4 billion to 9.9 billion lb, a spread of 2.5 billion lb. Industry sources indicate that the HDPE production volume made from the low-pressure capacity that is interchangeable between LLDPE and HDPE likely will be 500 million to 1 billion lb. If total nameplate HDPE capacity is as low as 7.4 billion lb, then the average operating rate in 1986 will be 95%. Nameplate capacity more likely is 7.7 billion to 7.9 billion lb, which would reduce the operating rate to the low 90% range.

An operating rate of 90 to 95% clearly indicates that demand for HDPE continues to be strong and that prices will hold up well. At a selling price of 30 to 33 cents per lb, HDPE ranks above both low-density polyethylene and LLDPE, priced below 30 cents a lb. Under pressure from lower crude oil prices and lower-than-expected demand for fuel products, proposed ethylene price increases may not last during this month. However, if they do, producers of HDPE may be able to pass on their raw material cost increase.

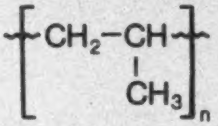
Molded products, mostly bottles or containers of one kind or another, take nearly two thirds of U.S. HDPE consumption. Bottles for milk (mostly 1-gal size), juices, syrup, and water are the largest-volume molded end products, and almost all are blow molded. For nonfood uses of molded bottles, motor oil containers have received much attention recently, as many oil companies switched from cans made entirely of metal, or fiber-board and foil laminates with metal ends, to HDPE 1-qt and 5-qt bottles. Rapid growth may be over for this use of HDPE, as well as for containers for household bleach, detergents, and various other nonfood products, because HDPE now practically dominates the market.

Industrial containers made of HDPE, both blow-molded and injection-molded, now are a major growth area. Some uniformity in design and changes in shipping regulations have helped to capture markets from steel containers in 5-gal and larger sizes. Resistance to corrosion can offset higher costs and difficulties in adapting existing filling equipment to use of HDPE containers. The capture of 1-gal paint cans from steel is being attempted, but success on a cost-competitive scale remains in the future.

Film use, at less than 10% of HDPE consumption, has been boosted by the shift from paper bags in the grocery and other retail areas. Frequently, the film used for bags is made of a blend of HDPE and another resin, often LLDPE, making estimates of the potential use in film difficult.

Exports at some 800 million to 850 million lb forecast for 1986 account for more than 10% of production. They have been expected to decline as new capacity for HDPE starts up in various parts of the world, but the new capacity quickly has become fully utilized, and that tends to shore up exports. Possibly after 1986 exports may begin to decline.

Key Polymers

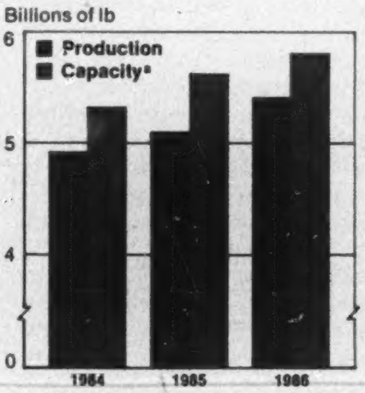


$$\left[\begin{array}{l} -CH_2-CH- \\ \qquad\quad\;\, | \\ \qquad\quad CH_3 \end{array}\right]_n$$

Polypropylene

- ***Output up steadily***
- ***Capacity easing***
- ***Prices steady***

PRODUCTION/CAPACITY



ᵃ First quarter.

MAJOR PRODUCERS

Amoco, Exxon, Himont, Shell, USS Chemicals

HOW MADE

Polymerization of propylene (sometimes with comonomers) aided by metallic salts and alkyls

MAJOR FABRICATED FORMS

Fibers and filaments 35%, injection-molded items 30%, film 10%

FOREIGN TRADE

Exports—rising to about 1 billion lb, imports—small and holding at about 10 million lb

PRICE

45 to 60 cents per lb, depending on grade

Polypropylene producers continue to enjoy high capacity utilization despite numerous rounds of expansions. Polypropylene production in 1986 is forecast to increase as much as capacity rose last year. Capacity in 1986 will expand about 200 million lb, the same as the expansion in 1985. As a result, U.S. nameplate capacity will reach 6 billion lb a year as 1987 begins.

Polypropylene output this year will exceed 5.4 billion lb, up some 300 million lb, or 6%, from the 5.14 billion lb produced in 1985, according to the Committee on Resin Statistics (CRS) of the Society of the Plastics Industry. Some market observers forecast that production will be up more than 8% this year. However, despite capacity additions due on stream in 1986 and strenuous debottlenecking achieved through catalyst and other technological changes, capacity may be insufficient to make such a volume.

If production totals 5.4 billion lb in 1986 and nameplate capacity for the year is 5.8 billion lb, then the average plant operating rate will be more than 93%. Should production total 5.6 billion lb and additions during the year bring nameplate capacity to 5.9 billion lb, the operating rate would be 95%. At that operating rate, resistance would be strong to stop production to make changes in grades; thus, shortages of certain less common grades might result.

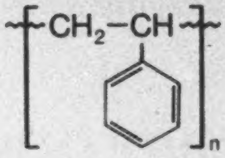
Even at 1985's high plant operating rate of about 91%, producers of polypropylene apparently could not meet demand. Sales and use of polypropylene in 1985 totaled 5.28 billion lb, according to CRS. Use exceeded production 135 million lb, or 2.5%. That drawdown of inventories might be replaced partially in 1986. Nevertheless, supplies will remain tight during most of the year.

Tightening supply has prompted price increases for polypropylene. After somewhat successful efforts late in 1985 to raise prices, declining crude oil and gas liquids prices again forced polypropylene prices down. The large reduction of use of lead alkyls in gasoline has lowered the value of propylene to refiners and has led refiners to try to sell more to chemical and polymer markets. That puts additional pressure on propylene prices. Consequently, polypropylene producers have been forced to pass through most of their raw material cost savings. Recent prices range from 31 to 33 cents per lb for the large-volume grades, down 4 to 7 cents per lb from the beginning of the year and well off from list prices. The outlook for price increases depends partly on gasoline demand and partly on ethylene prices. If ethylene prices increase (as producers have wanted) beginning this month, then propylene and polypropylene prices could rise as well, although probably not to the same degree. Until feedstock propylene costs rise significantly, polypropylene prices will hold at about their present levels.

Relatively low prices at a time when supplies are tight stem partly from the large exports of polypropylene. In 1985, exports totaled some 875 million lb, or 17% of production. They may rise to as much as 1 billion lb in 1986. Exporters hope to retain their markets by low prices that compete with foreign producers, some of which have new plants.

Increased U.S. consumption of polypropylene will account for most of the other 175 million lb of added output in 1986. Some of the additional production may go into inventory, but most will go into more of the same major-volume end products that were made in 1985. Those big end uses—film, fibers and filaments, packaging, transportation items (mainly battery cases, but also automotive trim parts), and consumer products—will continue to grow at fairly high rates, often spurred or reduced by fashion and innovation. Among the small uses, thermoplastic olefinic elastomers could grow fast enough to soon have an important effect on polypropylene demand.

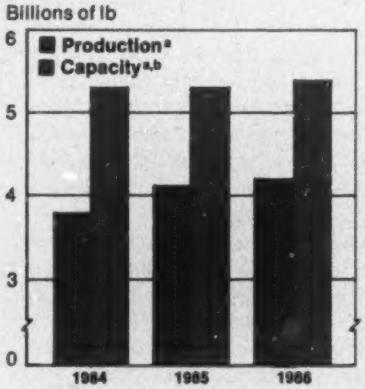
Key Polymers



Polystyrene

- ***Output up modestly***
- ***Capacity debottlenecked***
- ***Price forced up***

PRODUCTION/CAPACITY



[a] Straight and rubber-modified resins.
[b] First quarter.

MAJOR PRODUCERS

Arco Chemicals, Dow Chemical, Fina Chemicals, Huntsman Chemical, Monsanto

HOW MADE

Polymerization of styrene using initiators

MAJOR FABRICATED FORMS

Molded items 45%, extruded items 35%, expandable beads 15%

FOREIGN TRADE

Exports—small, may rise above 100 million lb, imports—small, about 30 million lb

PRICE

48 to 52 cents per lb; expandable beads cost about 20 cents more per lb

Unstable selling prices for both polystyrene and styrene (as influenced by benzene prices) now concern producers more than lack of a high-growth market for polystyrene. Overcapacity is continuing to keep pressure on polystyrene prices and add to pricing problems. No new high-growth market to ease the pricing problems is on the horizon—at least in part because current low margins in making polystyrene don't go very far in supporting product research and development.

Lower benzene prices, announced in June (to be effective then or on July 1), may put pressure on the price increases for various kinds of polystyrenes. Increases of 2 to 3 cents per lb for crystal and impact polystyrenes would have pushed most selling prices into the range of 32 to 35 cents per lb, which still is well below posted list prices.

When gasoline and crude oil prices were increasing in May, spot prices for benzene began to exceed contract prices of 80 cents per gal. Benzene contract prices were forecast to reach 90 cents per gal by July 1, and possibly higher, pulling prices for styrene, produced by alkylation of benzene with ethylene, higher as well. However, the gasoline demand increase of early summer has been less than expected, and prices for most aromatics (key ingredients in gasoline to provide high octane values) haven't increased as forecast. The result appears to be that price increases for polystyrene caused by efforts to pass through raw material price increases will erode this month.

Strong demand could help shore up polystyrene price increases. During the first quarter, polystyrene production was up 4% over that of the same 1985 quarter; it traditionally has been higher during the first half of the year. An increase of about 3% is forecast for all of 1986, but that level of production will not have a large enough impact on an overcapacity of more than 20% on a nameplate basis to help prices.

Second-quarter production of polystyrene is estimated to outstrip that in the first quarter. A particularly strong second quarter is traditional for polystyrene because many plants are shut down during the third quarter for vacations and maintenance, and additional inventory is required to meet demands.

Forecasts for production of polystyrene this year cluster around 4.2 billion lb, which is slightly higher (about 3%) than the 1985 production of 4.05 billion lb reported by the Committee on Resin Statistics of the Society of the Plastics Industry. Capacity to make polystyrene, as 1986 began, was 5.4 billion lb and unlikely to increase much this year. The operating rate for the year, therefore, will be 78% of nameplate capacity, up slightly from last year's rate. Polystyrene has the lowest capacity utilization of the major-volume thermoplastics.

In 1986, all of the major end uses of polystyrene likely will hold their share of the market. Many—such as packaging and other disposables, electronic and electrical components, and construction materials—are well established and will depend on the general economy for growth. About one third of polystyrene consumption in the U.S. stems from packaging, with uses of the packages ranging over most consumer products such as cups, egg cartons, and berry boxes. Growth in packaging uses will be low, probably holding at 2% annually.

Other use categories—housewares and furniture items, toys and other recreational items, and food serviceware, as well as electronics and construction—require 350 million to 500 million lb each of polystyrene. Except for the electronic components area, none of those uses are growing very fast. Miscellaneous uses of polystyrene account for about 10% of consumption, and none of those small uses will grow fast enough to pull the resin back onto a high growth rate track during this decade.

Top Liberal Arts Colleges Need More Money for Basic Science

Oberlin College study says schools must invest $1 billion over next decade to maintain and enhance their present strong position in science

If the nation's top liberal arts colleges are to maintain and enhance their present strong position in basic science, they must invest about $1 billion—over and above current commitments—during the next decade. That's perhaps the most important message in "Maintaining America's Scientific Productivity: The Necessity of the Liberal Arts Colleges," a recent report by provost Samuel C. Carrier and research director David Davis-Van Atta of Oberlin College.

Preliminary findings from the new report were presented at the Second National Conference on the Future of Science Programs at Liberal Arts Colleges. Some 50 college presidents from 19 states attended the meeting, which was held last month at Oberlin. The final version of the report will appear this fall.

Where the billion would go

$ Millions	Capital needs
Additional faculty positions	**$ 369.1**
Faculty salary and benefits	116.2
Support staff salary and benefits	23.1
Materials and supplies	33.2
Facilities construction	152.9
Facilities maintenance	43.7
Maintain and enhance teaching and research	**531.8**
Starter grants	58.2
Probationary period research leaves	27.2
Competitive faculty compensation adjustment	152.2
Student research assistants	118.3
Scientific equipment and instrumentation	175.9
Maintain and enhance labs and classrooms	**$ 150.0**
Replace outdated buildings	48.2
Renovate aging buildings	101.8
TOTAL	**$1050.9**

At the first such meeting last year, Carrier and Davis-Van Atta presented another report, "Educating America's Scientists: The Role of the Research Colleges." That report pointed up just how important a role those 50 colleges and other U.S. liberal arts colleges played in keeping the scientific pipeline full.

For example, although nationally there has been "significant erosion in freshman interest in the basic sciences," the 50 schools participating in the conference have actually increased their share of freshmen intending to major in a science. That share now almost equals the share of "the highly selective private universities."

Moreover (according to the 1985 report), those same 50 colleges' science graduates go on to earn doctorates in a significantly higher proportion than do graduates of either the Ivy League schools or the 20 top-rated research universities. One of the main reasons for this success has been the increased number of women interested in science. Women now form a majority of science graduates at those 50 liberal arts colleges, with their numbers rising 14% in the past 10 years.

However, those 50 colleges, compared with the private research universities, are largely tuition-dependent, endowment-poor, and underfunded by both government and industry. Although the colleges produce 7% of the nation's basic science undergraduate degree recipients, they receive less than 0.5% of National Science Foundation expenditures. And, the report notes, "Enrollment and funding are moving in opposite directions."

The 1986 study reflects a continuation of those trends. In 1985, it notes, the number of freshmen intending to major in a science increased slightly, to nearly 30% of the total.

One of the main reasons the liberal arts colleges succeed in attracting potential science majors is their faculties. Typically, they are "university caliber," with members actively engaged in research. However, those "productive, practicing scientists" also teach students at all levels. In addition, students themselves are also actively engaged in research. Nearly 30% of all scientific articles from the colleges are jointly authored by undergraduate students and faculty mentors.

Liberal arts science faculties are:

- **Overwhelmingly male (89%)**
- **Virtually all white (96%)**
- **Mostly tenured (69%)**
- **Almost all full-time (97%)**
- **Relatively old (average age 44)**

Carrier and Davis-Van Atta profile the liberal arts college science faculties: Overwhelmingly male (89%). Virtually all white (96%). Most (69%) are tenured. Almost all (97%) are full-time employees. Average age is 44.1 years—"relatively old," according to the study.

The study notes that the percentage of women science faculty members has nearly doubled over the past 10 years, from 5.8% to 11%.

Organic Marine Geochemistry

Organic Marine Geochemistry
305
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Mary L. Sohn, *Editor*
Florida Institute of Technology

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However, the percentage of minorities is "shockingly low." For example, the number of black science faculty members is less than 1%.

"Even though this dismal record is no worse than that of most research universities, it is nonetheless unacceptable," says Oberlin president S. Frederick Starr. "The leading liberal arts colleges should undertake a special effort to train and attract black faculty members in the basic sciences."

As to scientific instrumentation and equipment, a wealth of detail in the study suggests that the liberal arts colleges, like other institutions of higher education, are getting along but would like to have more and better equipment. Classrooms and laboratories don't seem to be a major problem. The study does note, however, that the average age of buildings is almost 50 years and that only 12% of the buildings are less than 10 years old.

All in all, a pretty good record for the 50 colleges. But, the study asks, "What is needed to sustain and build this record?" The answer: "About a billion dollars." That answer assumes a 1.1% annual growth in teaching staff and also in support facilities and personnel. That translates into a capital requirement of about $369 million.

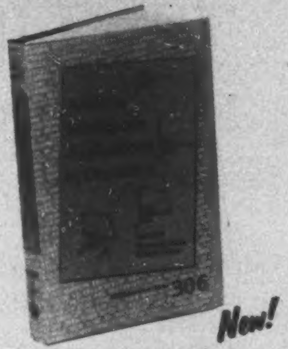
In addition, $531 million will be needed to "maintain and enhance teaching and research" and another $150 million to "maintain and enhance laboratories and classrooms."

Carrier and Davis-Van Atta note that computing what are actually annual costs (for example, the cost of maintaining additional faculty members) in terms of the capital needed to support those costs is a simplifying assumption. But they believe it's a reasonable assumption, since such expenses do indeed represent a claim on capital, even though they don't add to the capital base of the school.

"The fundamental conclusion of this study is that the colleges, individually and collectively, should launch campaigns to reach the billion dollars needed," Starr observes. "Just how this formidable enterprise is to be organized and undertaken is a question that looms large."

Ward Worthy, Chicago

Artificial Intelligence Applications in Chemistry



Thomas H. Pierce and Bruce A. Hohne, *Editors*
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FINAL PROGRAM
ACS meeting in Anaheim
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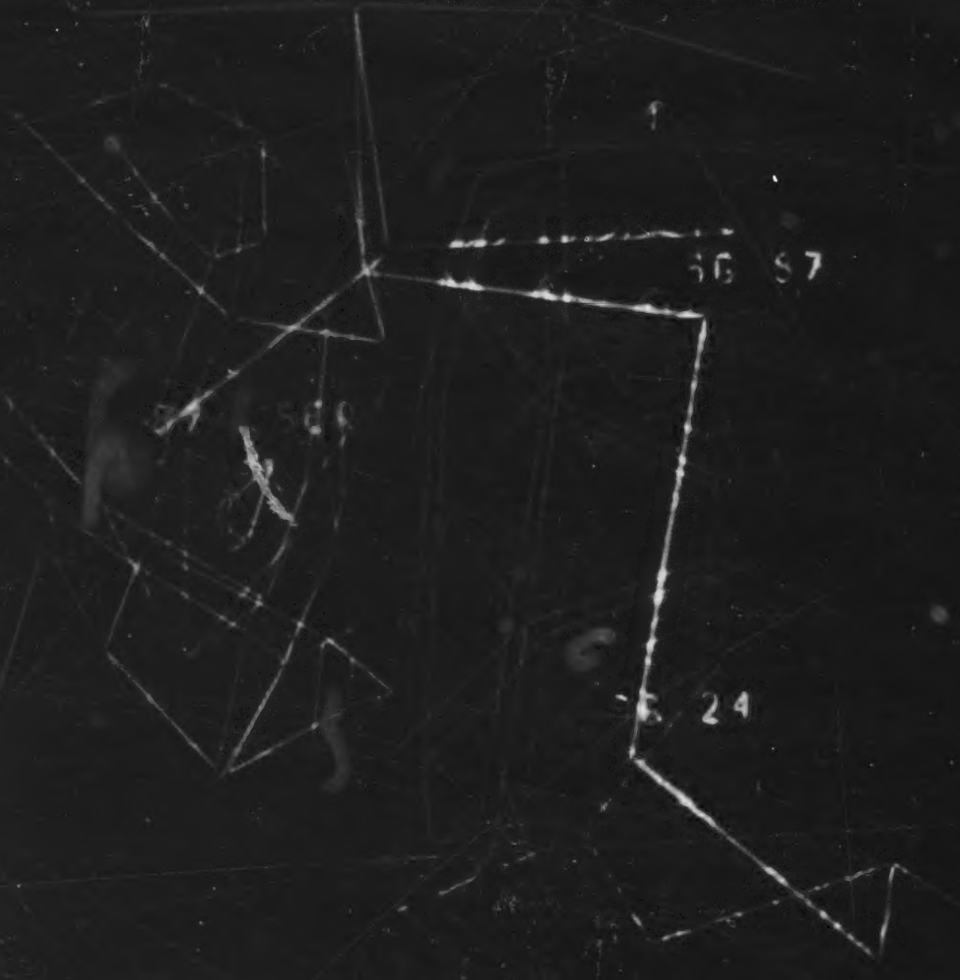
JULY 14, 1986

CHEMICAL & ENGINEERING NEWS



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Enzyme Chemistry

Mutagenesis techniques shed light on structure-function relationships Page 7

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CHEMICAL & ENGINEERING NEWS

JULY 14, 1986

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- **Equal Employment Opportunity Commission accuses Du Pont of age discrimination in its early retirement program last year.** **Page 5**
- **Du Pont to acquire health care unit, packaging business, and half-interest in distributor of crop protection products.** **Page 5**
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Cover: Difference electron density map superimposed on wild-type structure and on initial crystallographic model of mutant subtilisin. Computer graphic courtesy of Genentech Inc. and Genencor

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LETTERS

Simple arithmetic

SIR: Although it is easy, as Douglas Frost writes (C&EN, May 12, page 2), to argue in favor of promoting the metric system of measurement, in all things and everywhere, it is time for teachers, technologists, and scientists to consider the virtues of two-way communication recommended by James Hay on the Editor's Page (page 3).

1. The old measures are so easily converted by technologists, etc. to the metric scales when necessary; especially now that we have electronic calculators.

2. The old measures, especially in length (including area and volume), have the notable merit of being divisible by three without encountering recurring decimals. Thus they are much easier for common people to understand.

3. The vested interest of generations of documentation and use of inches, feet, yards, acres, and miles should not, and cannot, be changed lightly without immense oppressive bureaucracy.

4. Do the metricalists propose to change the units of time and angular measurement from their basis of 60 in seconds and degrees? If not, they cannot even claim that they are creating a unified system.

5. The Centigrade scale of temperature is just as arbitrary in its basis as that of Gabriel Fahrenheit. Must we impose the change on the medical profession?

For these and other less glaringly obvious reasons, let us accept human nature and continue with our different and imperfect systems, and teach our young, and our old, to deal with the differences by simple arithmetic when needed.

R. M. Deanesly
Berkeley, Calif.

Implications of Folkers' speech

SIR: I wish to make two comments on Karl Folkers' Priestley Medal Address (C&EN, April 21, page 27). First, ACS has long had a policy discouraging the presentation of papers recommending new therapies for disease unless such therapies have been confirmed by appropriate medical authorities. Although the Priestley Medal Address is not the same as a contributed research paper, it is far more well attended and publicized than the average paper. By its very nature it carries the weight of authority. Thus, I think it inappropriate that Folkers reports "positive results" from a study of vitamin therapy in psoriasis, although he admits that the studies are not complete and results are not clear-cut. Public reports of positive therapeutic results unaccompanied by data should be made after acceptance of a research report by a referred journal.

Second, Folkers confuses the fact that the 10th edition of the Recommended Dietary Allowances (RDAs) was not released with the issue of whether people with diseases may have higher requirements for vitamins or other nutrients than healthy people. The RDAs are meant to be values for recommended dietary intake by healthy people. Some of the difficulty in defining the RDAs undoubtedly comes from the difficulty in defining "health." However, if sick people need much larger than ordinary intakes of vitamins or minerals, then we are talking about pharmacology, not nutrition. I think statements such as, "If science does not know the requirement . . . how can anyone criticize a dose from a microgram to a gram?" are not very responsible. Such statements encourage the lay public to undertake self-supplementation with megadoses of various vitamins and minerals without any knowledge of the possible adverse effects of unbalanced intakes.

As a member of both the American Institute of Nutrition and the American Chemical Society, I am concerned about the implication of Folkers' speech. He is certainly correct when he says more research is needed about nutritional requirements in both health and disease. However, in our eagerness to make the world a better place through chemistry we must not forget our responsibility to the lay public, who often will believe what we scientists tell them.

Phyllis E. Johnson
USDA, ARS, Human Nutrition Research Center
Grand Forks, N.D.

Values clarification

SIR: Joseph F. Coates, in his review of William W. Lowrance's new book (C&EN, May 12, page 40), manages to pontificate on matters on which he has obviously not done his homework. He remarks, "The current vogue among ethicists is values clarification." I don't know where Coates has been hanging out for the past 20 years, but it is clear that it hasn't been in the periodical room among the philosophy and ethics journals.

Values clarification has never been in vogue among philosophers and ethicists. It was spread among gullible public school officials and teachers by people such as Sidney Simon.

Values clarification has received powerful philosophical criticism, not support. See, for example, "Where the Values Movement Goes Wrong," by Edwin J. Delattre and William J.

Continued on page 120

Correction

• May 19, pages 45 and 59: California Polytechnic State University granted a total of 43, not 70, bachelor degrees in chemistry in 1985.

Biotechnology Stocks Outraced Stock Market in First Half

Their prices, however, are rising more slowly now, as initial offerings fill market and investors await product developments

David Webber, C&EN New York

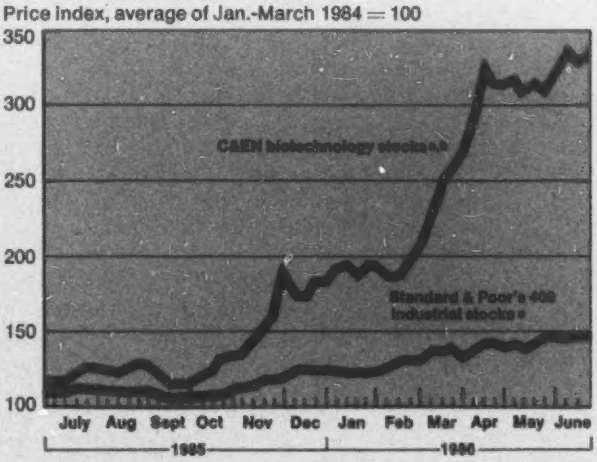
The biotechnology stock market, scene of red-hot growth throughout the first three months of the year, has now cooled off considerably. In the 12 months ending June 27, 1986, C&EN's biotechnology stock index increased 180%; Standard & Poor's 400 industrial stocks index rose 32%. In the first half of 1986, the biotechnology stock index shot up 86%; Standard & Poor's 400 climbed 20%. Since mid-April, however, biotechnology stock values have grown just 2%, half the appreciation of the S&P measure.

C&EN's biotechnology stock index is based on the composite market value—the product of stock price and number of shares of common stock outstanding—of a representative group of 18 biotechnology-based companies.

Several factors have worked to slow the rate of growth of biotechnology stock values. For one thing, the elements that combined to create the great surge in stock prices last fall—two high-priced acquisitions of biotechnology companies, government approval of Genentech's recombinant DNA human growth hormone, and encouraging results from human trials of interleukin-2—in general have now been factored into company stock prices by investors.

The most positive commercial development this spring was the Food & Drug Administration's approval of α-interferon for the treatment of hairy cell leukemia. The bringing to market of the first recombinant interferon—once expected to be the confirmation of genetic engineering's commercial promise—was a major achievement and helped raise stock prices. The approval, in particular, dusted off the prestige of Biogen, which developed the version of α-interferon being marketed by Schering-Plough. But the event lacked the broad, explosive impact of last year's developments, largely because the product's market, as constrained by FDA's limited indica-

Biotechnology stocks rose four times faster than stock market this year . . .



a Reindexed to weighted average for Jan.-March 1984 period to show relative change. Prices as of Friday close each week. b Based on stock prices for Advanced Genetic Systems, Amgen, Applied Biosystems, Biogen, Bio-Response, California Biotechnology, Centocor, Cetus, Chiron, Collaborative Research, Damon Biotech, DNA Plant Technology, Enzo Biochem, Genentech, Immunex, Molecular Genetics, Monoclonal Antibodies, and Ribi Immunochem.

. . . and prices of many of these stocks are still near their 52-week high

Company	Recent price[a]	% change[b]	52-week range High	52-week range Low
Advanced Genetic Sciences	$ 5	18%	$ 6⅛	$ 2½
Amgen	24¾	203	29⅜	6¾
Applied Biosystems	49½	106	51¾	18
Biogen	17¼	130	20⅝	7
Bio-Response	7⅜	9	10¾	5
California Biotechnology	22½	105	29¾	9¼
Centocor	41¾	126	45	14½
Cetus	37⅛	245	42½	10½
Chiron	25¼	216	31¾	4¾
Collaborative Research	7⅝	85	10¾	2¾
Damon Biotech	7¾	22	10½	5⅜
DNA Plant Technology	16½	94	21¼	7¼
Enzo Biochem	14½	18	19¼	10
Genentech[c]	92¾	293	98¾	19⅝
Immunex	19	223	20¼	4
Molecular Genetics	10¾	59	15½	6⅛
Monoclonal Antibodies	22¾	153	29	8¼
Ribi ImmunoChem	9	11	11½	5

a As of close on Friday, June 27, 1986. b June 26, 1985, to June 27, 1986. c Adjusted for 2-for-1 stock split in February 1986.

tion, is not likely to be particularly large.

Many private biotech firms went public this spring

Company[a]	Location	Number of shares (millions)	Initial offering price	Date of offering	Recent price[b]	% change
Biotherapeutics	Franklin, Tenn.	1.73[c]	$11	June 17	$21	91%
Calgene	Davis, Calif.	1.75	13–16	d	—	—
Cistron Biotechnology	Pine Brook, N.J.	na	na	d	—	—
Cytogen	Princeton, Mass.	3.00	13	June 18	11¾	−10
Genetics Institute	Cambridge, Mass.	2.88	29¾	May 20	26½	−11
Genzyme	Boston	3.25	10	June 5	12½	25
Hana Biologics	Berkeley, Calif.	1.43	10	June 5	7⅝	−24
Ingene	Santa Monica, Calif.	2.00	5	June 17	8	0
NPI	Salt Lake City	na	na	d	—	—
Oncogene Sciences	Mineola, N.Y.	2.30	6	April 3	5¼	−13
Repligen	Boston	11.50	11½	April 29	10⅞	−5
Synergen	Boulder, Colo.	1.74	11	March 7	11¾	7
Syntro	San Diego, Calif.	2.10	9–11	d	—	—
T Cell Sciences	Cambridge, Mass.	0.79[c]	16	May 15	21¼	33
Liposome Co.	Princeton, N.J.	2.50	8–10	d	—	—
Xoma Corp.	Berkeley, Calif.	2.30	16	June 6	16¼	2

a Representative selection of biotechnology firms making initial public offerings since January 1986. b As of close, July 3, 1986. c Units of common stock plus rights to purchase more stock. d In process. na = not available.

The other major factor has been the drain on investment capital. Rushing to exploit the tremendous popularity of biotechnology stocks, many public companies issued secondary stock offerings while many other private firms, some of which had moved too slowly to benefit from the 1983 boom market and others of which are just a few years old, made initial public offerings. According to Linda I. Miller, biotechnology analyst at Paine Webber, investors have plowed about $500 million into initial and secondary offerings of biotechnology company stock since last fall.

Now, some analysts believe, the market may be nearing saturation with new stock. Teena L. Lerner, vice president at L. F. Rothschild, Unterberg, Towbin, points out that issues have been selling much more slowly recently. Institutional investors complain that they do not have time to go through all the biotechnology-related prospectuses piled on their desks, she says.

Parag Saxena, assistant vice president in charge of Citibank's emerging health care fund, agrees. "There's no juice left" in initial public offerings, he says. "The last several deals have gone at discounts." In the May offering by Genetics Institute, for example, stock in the well-respected firm was offered initially at $29¾, but the price fell as low as $24¾, he notes.

Miller points out that an equally important factor in the initial public offering market is continuing investor worry that too many companies are developing similar products. Both initial and secondary offerings from firms that have differentiated themselves are selling well, she says.

At this point, investors are believed to be awaiting a new series of positive developments, particularly in terms of product approvals. All eyes are on the hepatitis B vaccine developed by Chiron for Merck. Analysts expect FDA approval for the vaccine, which would be the first commercialized genetically engineered human vaccine, will come later this year. Approval undoubtedly would boost interest in stock in Chiron and companies with related projects—Biogen and Amgen, for instance—as well.

Even more eagerly awaited is approval of Genentech's tissue-type plasminogen activator (TPA), generally expected to be the first blockbuster-sized biotechnology product. Approval is generally expected in 1987, although optimists think FDA could send the heart attack treatment, eagerly sought by physicians, to market as early as this December. Other companies with TPA projects, such as Genetics Institute and Integrated Genetics, would also probably benefit in the stock market as a result.

Other major product approvals, such as for other interferons, could come next year. In the meantime, some stocks could gain from good progress reports on the continued testing of interleukin-2 in cancer patients.

Saxena believes it will take not only "significant events," as he puts it, but a series of them closely bunched to give biotechnology stocks the spark they need to rise above their current plateau. "My sense is that investors are still not really participating in the market but are looking for a pull-back in stock prices," he says. "So we have this dry spell now. Then, if there is a spurt of good news, prices will take off again."

Last fall, a major spark was the successive acquisitions of Hybritech by Eli Lilly and of Genetic Systems by Bristol-Myers, both in the $300 million range. The purchases validated the idea that there is a "technology value," as Miller puts it, to biotechnology companies, regardless of whether they already have major products on the market or are even operating profitably. The technology value is undoubtedly still there, but analysts do not expect any more major acquisitions soon.

"It's less likely, because companies are more well-funded now," Miller remarks. "They don't need big partners right now. I think acquisitions have run their course for this stock market cycle."

Furthermore, investment criteria for biotechnology-based companies are expanding. Investors are still focusing on product development, earnings, and management structure in their deliberations. Those are constant elements in the investment decision, of course, but the beginning trickle of genetically engineered products entering the marketplace means that, for the first time, investors will be able to judge companies on how well their products sell as well. □

Army Proposes Burning Existing Chemical Weapons On-Site

Decision avoids risk of transporting arms to a central facility, but communities near weapons storage sites are likely to oppose plan

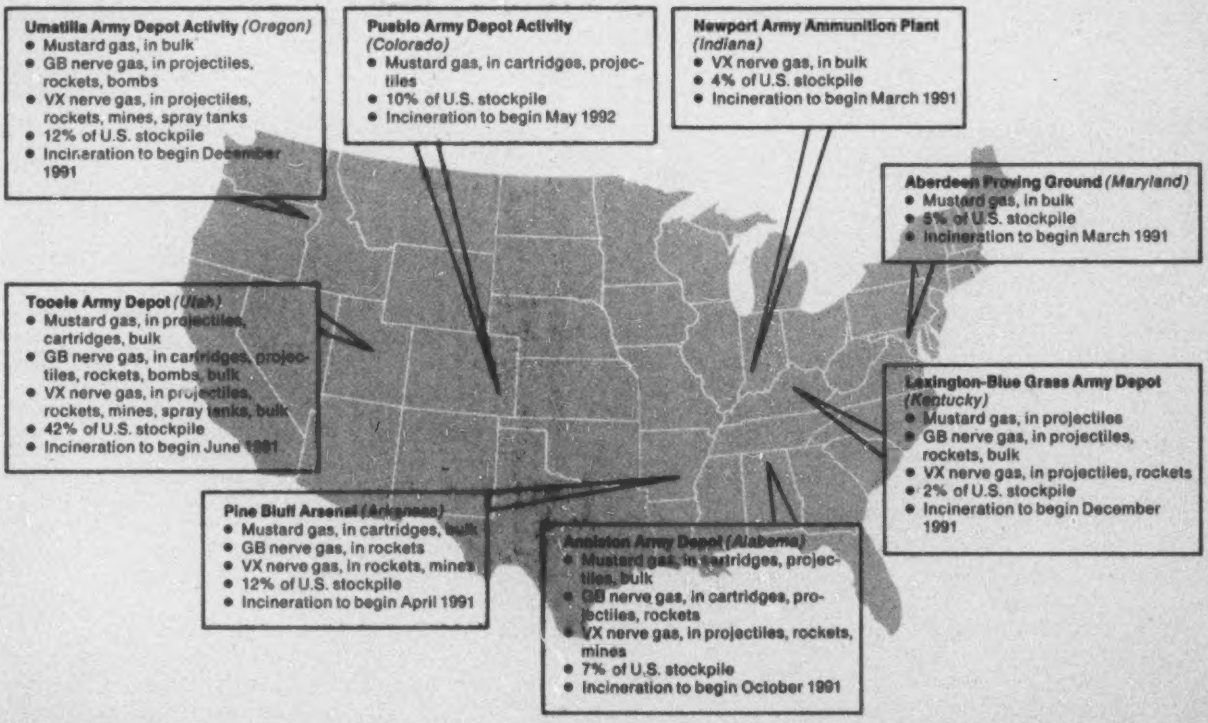
Under Congressional charge to destroy all existing chemical weapons by 1994, the Army has announced its preliminary decision to burn those weapons at the eight sites in the U.S. where they are now stored, thus avoiding the risks inherent in transporting them to one or two central disposal sites. The decision is likely to meet stiff opposition from the communities surrounding the eight sites and to stir up Congressional debate.

In selecting the on-site option, the Army rejected shipping all munitions and chemical agents to a national disposal site at Tooele Army Depot near Salt Lake City or to two regional sites. Under the regional plan, chemical stocks in western states would be shipped to Tooele, and those in eastern states would be transported to Anniston Army Depot, about 50 miles from Birmingham, Ala.

"There is no alternative for taking care of the stockpile that doesn't have a risk, including doing nothing, deputy undersecretary of the Army Amoretta M. Hoeber says. The risks associated with disassembling the weapons and incinerating the hardware and chemical agents are about the same whether the weapons are destroyed on the site or transported to regional sites. However, transportation by rail adds risks, including the potential for a terrorist attack against a fully loaded train, Hoeber explains.

Destruction of existing nerve and mustard gases in bulk form, as well as chemical-filled rockets, artillery shells (projectiles), mines, and bombs,

Incineration of chemical stockpile may take place at these sites



Umatilla Army Depot Activity *(Oregon)*
- Mustard gas, in bulk
- GB nerve gas, in projectiles, rockets, bombs
- VX nerve gas, in projectiles, rockets, mines, spray tanks
- 12% of U.S. stockpile
- Incineration to begin December 1991

Pueblo Army Depot Activity *(Colorado)*
- Mustard gas, in cartridges, projectiles
- 10% of U.S. stockpile
- Incineration to begin May 1992

Newport Army Ammunition Plant *(Indiana)*
- VX nerve gas, in bulk
- 4% of U.S. stockpile
- Incineration to begin March 1991

Aberdeen Proving Ground *(Maryland)*
- Mustard gas, in bulk
- 5% of U.S. stockpile
- Incineration to begin March 1991

Tooele Army Depot *(Utah)*
- Mustard gas, in projectiles, cartridges, bulk
- GB nerve gas, in cartridges, projectiles, rockets, bombs, bulk
- VX nerve gas, in projectiles, rockets, mines, spray tanks, bulk
- 42% of U.S. stockpile
- Incineration to begin June 1991

Lexington-Blue Grass Army Depot *(Kentucky)*
- Mustard gas, in projectiles
- GB nerve gas, in projectiles, rockets, bulk
- VX nerve gas, in projectiles, rockets
- 2% of U.S. stockpile
- Incineration to begin December 1991

Pine Bluff Arsenal *(Arkansas)*
- Mustard gas, in cartridges, bulk
- GB nerve gas, in rockets
- VX nerve gas, in rockets, mines
- 12% of U.S. stockpile
- Incineration to begin April 1991

Anniston Army Depot *(Alabama)*
- Mustard gas, in cartridges, projectiles, bulk
- GB nerve gas, in cartridges, projectiles, rockets
- VX nerve gas, in projectiles, rockets, mines
- 7% of U.S. stockpile
- Incineration to begin October 1991

Note: There are chemical stockpiles on Johnston Island, Pacific Ocean, and at U.S. Army bases in West Germany. Johnston Island stocks are to be incinerated first, in 1989. **Source:** Army is expected to cost $2 billion, no matter which option is ultimately chosen. Public hearings on the destruction plan will be held during the next three months. The Army will issue its final environmental impact statement in December. And next January, Army Secretary John O. Marsh Jr. will issue his final decision.

In making his decision, Marsh will have to factor in Rep. Larry J. Hopkins' (R.-Ky.) strong opposition to the Army's incineration proposal. Hopkins is a supporter of the binary modernization program. In exchange for this support, he authored the amendment that requires the existing unitary chemical weapons be destroyed by incineration by Sept. 30, 1994. Unfortunately for the Army, Hopkins represents Madison County, which is home to the Lexington-Blue Grass Army Depot. He wants weapons that are stored there to be transported to another site for destruction. As a member of the House Armed Services Committee, he is in a position to see that his desire is fulfilled.

Hopkins argues "that the incineration process has never been properly validated under actual operating conditions." Countering that, Charles Baronian, deputy program manager and technical director for the Army's chemical demilitarization program, says: "We are satisfied from an engineering viewpoint that we have a good fix on the methodology to incinerate nerve agents and mustard. We've burned several thousand pounds of GB and VX nerve gas at the test incinerator at Tooele Army Depot. And in the early 1970s we incinerated 6 million lb of mustard gas at Rocky Mountain Arsenal in Denver." All safely, Baronian declares.

Hopkins' main concerns are that, "we have only about 1.6% of the total stockpile, the least amount stored at any of the sites ... [And] we have virtually the highest population density immediately surrounding the Madison County depot [of] any of the other sites."

Army spokesman Phil E. Soucy says Hopkins' argument is not with the Army. Rather it is "with the surrounding communities, the rest of the state, and the surrounding states." Berea, Ky., which is also near the depot, already has passed an ordinance prohibiting the transportation of chemical weapons through the town.

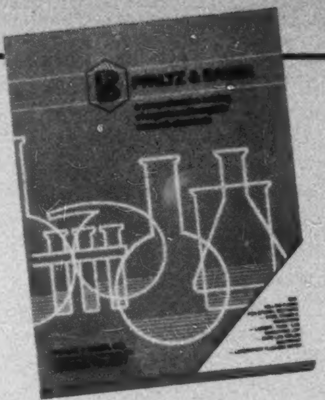
The Army's problem with Hopkins is overshadowed by the prickly dilemma West Germany presents. President Reagan has formally said the U.S. would remove its chemical stocks from its Army bases in West Germany by 1992. These are the only forward-deployed chemical weapons and therefore an important part of current U.S. deterrent.

How, when, and where those stocks will be moved is not addressed by the Army's recent preliminary decision. George A. Carruth, chief of the Army's chemical and NBC defense division, says the chemical stocks in West Germany "are subject to negotiation between the U.S. and West Germany, and when they are removed is partly up to the desires of West Germany." He wouldn't comment on the possibility that these weapons might be burned on-site in West Germany. But transportation across Germany and perhaps other European states is likely to raise an uproar.

Equally contentious would be transportation of the weapons to the continental U.S. for destruction. When chemical weapons were removed from Okinawa in the late 1960s and early 1970s, they were to be transported to and stored at a West Coast Army depot. The uproar was so great that Congress passed a law in the early 1970s prohibiting their importation. Those weapons were sent to Johnston Island, about 800 miles southwest of Hawaii, for storage. An incinerator is now being built on the island to destroy the chemical weapons. If all goes as scheduled, they will be the first of the U.S. stockpile to be destroyed, in June 1989.

Soucy says removal of the West German stocks "is going to be a State Department issue. The Army will execute any instructions it receives." An aide for Hopkins says the presumed instructions are "that the chemical weapons in West Germany will be moved to Johnston Island for destruction." There is no native constituency there to protest.

Lois Ember, Washington



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NEWS

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- **Earnings of many U.S. chemical companies increased for the second consecutive quarter.** Page 6

- **FDA approves use of human vaccine for hepatitis B that was developed by recombinant DNA techniques.** Page 7

- **Union Carbide will sell its agricultural chemicals division to reduce corporate debt.** Page 7

- **Jean-René Fourtou becomes new chairman of Rhône-Poulenc in French prime minister's drive toward privatization of industry.** Page 8

- **Metal matrix composite materials will be tested in vertical tails of Air Force fighter planes at Lockheed-Georgia facility.** Page 8

Cover: Organic chemist carries out drug research at Smith Kline & French Laboratories' new R&D complex in Upper Merion, Pa.

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Special Report

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Chemical Stocks Outperform Other Industrials During Past 12 Months

Index is up almost 50% from a year ago, but has fallen from all-time high seen at beginning of this month

William J. Storck, C&EN New York

Stock market indexes have been setting new records recently. Although the Dow Jones Industrial Average has fallen in the past couple of weeks from its all-time high of 1909, analysts believe it is only a matter of time before it gets rolling again to still higher peaks.

And, not to be outdone, C&EN's chemical stock index itself hit a record high 433 (1957 = 100) at the same time. In the past 12 months, the chemical stock index continued to outperform the Dow Jones average. In the period between July 19, 1985, and July 18 of this year, C&EN's index rose 47% whereas the Dow increased just 31%. In fact, in that time the chemical stock index beat all other major stock market indicators. During the period, the New York Stock Exchange Composite Index climbed 20%, the NYSE Industrials 21%, the American Stock Exchange Index 13%, the Over-the-Counter Composite 24%, the OTC Industrials 20%, and the Standard & Poor's 500 and the S&P 400 Industrials both up 21%.

C&EN's chemical stock index is based on the weighted market value of the stocks of American Cyanamid, Celanese, Dow Chemical, W. R. Grace & Co., Hercules, Monsanto, and Union Carbide.

In all fairness, however, it must be pointed out that the chemical stock index seems to be becoming more volatile than the more broadly based indexes. For instance, while the Dow Jones Industrials fell 6.9% in the past few weeks from its high, the C&EN index dropped 7.9%.

If stock prices are seen to be predictive, the trend bodes well for the chemical industry over the next few months. Many analysts see the chemical industry growing in terms of earnings if not in volume over the next half year as companies continue to get cost breaks on raw materials and as productivity and efficiency programs continue to pay off. Longer term, there is hope that the foreign trade picture will improve as chemicals regain some of their traditional overseas markets lost during the period when the dollar was very strong against other currencies.

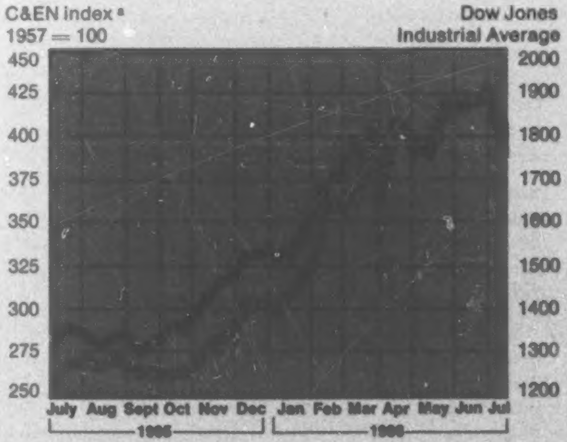
Analysts like to point to the declining price of oil and natural gas feedstocks as a case for improved earnings in the next few months. But many caution that at the same time, chemical prices also are falling. The key to improved earnings is that the chemical price not fall so fast and so quickly as the feedstock costs. So far, chemical price declines have lagged drops in raw material costs.

Analysts also point out that most of the major restructuring moves have already taken place and that the shucking off of less than desir-

Chemical stock index outperforms all other indexes

	July 18, 1986	July 19, 1985	% change
Dow Jones Industrial Average	1777.98	1359.54	30.8%
New York Stock Exchange Composite	136.35	113.26	20.4
New York Stock Exchange Industrials	155.36	128.84	20.6
American Stock Exchange Index	267.67	236.84	13.0
Over-the-Counter Composite	381.07	307.76	23.8
Over-the-Counter Industrials	376.14	313.76	19.9
Standard & Poor's 500	236.36	195.13	21.1
Standard & Poor's 400 Industrials	261.47	215.83	21.1
C&EN chemical stock index	399	271	47.2

Chemical stocks have risen faster than major industrials in past year



a C&EN weighted stock price index of American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Hercules, Monsanto, and Union Carbide.

able businesses and plants, the shutdown of outmoded facilities, and the cutting of employees over the past year or more have poised the chemical industry for good earnings leverage in the coming months. Also, with the greater efficiency of the industry, a moderate upward swing in capacity utilization could bring an increase in earnings that would be out of scale with the capacity use increase.

This swing in capacity utilization could easily be brought about by an increase in chemical exports or a decline in imports. With the dollar 25% or more weaker than it was a year ago, U.S. chemicals become much more competitive on world markets. The result could be an increase in exports from the U.S. as domestic companies find it easier to sell abroad. More likely than that in the next few months, according to economists, is that foreign imports into the U.S. will decrease as the declining dollar raises the price of imported chemicals.

The idea of increasing earnings in the next few months is reflected in the price/earnings ratios (price per share of stock divided by earnings per share) of the companies on the list. Although it is said that stock prices indicate the direction of the economy as much as six months into the future, the price/earnings ratio is based on the past 12 month's income. Thus, as the price/earnings ratio moves higher, it indicates that stock buyers think that earnings are going to grow.

Right now the price/earnings ratios for many chemical companies are unusually high. In recent years, stock prices for chemical companies have averaged about 10 to 15 times earnings, but as the value of their stock has moved up in advance of earnings so, of course, have the ratios for individual companies. Thus, a situation currently exists where Dow Chemical stock is selling at 84 times earnings, for example, and International Minerals' stock price is 54 times earnings per share.

Of the companies that make up the index, Celanese's stock has shown the best performance in the past year, rising more than 58%. At least some of that rise, however, must be attributed to the company's stock buy-back program, which has had much of the same effect as a reverse stock split. Following Celanese's stock performance are an annual rise of 51% for Dow Chemical, 41% for Union Carbide, 33% for American Cyanamid, 26% for Hercules, 25% for Monsanto, and 19% for W. R. Grace. Monsanto and Grace have had problems because of their ties to the agricultural chemicals industry.

Not surprisingly, shares of many of these companies are selling near their 12-month highs. American Cyanamid stock is down 8% from its high, Dow about 10%, Union Carbide and Hercules about 11%, Monsanto 12%, and Grace 18%.

On a broader list of 30 chemical firms, only six are selling for less than they were a year ago. For First Mississippi stock, the price is 35% below its year-ago level, for Freeport-McMoRan 23%, for International Minerals 24%, for Ethyl 18%, for Petrolite 15%, and for Reichhold 15%. Three of these companies—First Mississippi, Freeport, and IMC—are tied to agriculture, and Petrolite is in oil field chemicals, both highly troubled industries at present.

Other leaders in gains on the list include Crompton & Knowles, up 44%; Chesebrough-Pond's, up 42%; International Flavors, up 36%; Olin, up 35%; Witco, up 31%; Rohm & Haas, up 30%; Loctite, up 26%; and Lubrizol, up 25%.

Companies other than those on C&EN's chemical stock index that are selling near their highs include Crompton & Knowles, H. B. Fuller, PPG Industries, International Flavors, and Ethyl. □

Most stock prices are up handsomely from a year ago

	Stock price July 18, 1986	% change from year earlier	% change from 12-month high	% change from 12-month low	Price/earnings ratio[a]	Dividend yield, % of price
Air Products	$ 32½	17.1%	−21.9%	26.2%	13	2.5%
American Cyanamid	72½	32.7	−8.2	49.1	26	2.6
Celanese	205	58.3	−13.1	82.2	13	2.4
Chemed	34½	15.0	−13.8	30.8	14	4.5
Chesebrough-Pond's	47	42.4	−10.7	51.6	15	4.1
Crompton & Knowles	33	43.5	−5.4	52.6	14	3.8
Dow Chemical	55	50.7	−9.7	64.2	84	3.3
Essex Chemical	29½	5.8	−20.3	60.5	17	2.3
Ethyl	19½	−18.3	−13.3	85.7	21	1.6
First Mississippi	5⅞	−34.7	−40.5	11.9	9	4.1
Freeport-McMoRan	15½	−23.0	−27.9	8.8	—	10.6
H. B. Fuller	29⅛	4.0	−6.0	100.9	16	1.3
W. R. Grace	49⅝	18.9	−18.3	39.8	23	5.7
Hercules	49¼	26.3	−10.5	43.8	19	3.6
International Flavors	43¼	35.7	−11.5	52.4	22	2.7
International Minerals	32⅝	−24.3	−25.9	9.7	54	3.1
Loctite	40½	26.1	−12.4	39.7	19	2.2
Lubrizol	30	25.0	−14.6	51.9	17	3.9
Monsanto	65¾	24.9	−12.2	61.8	—	3.9
Morton Thiokol	34½	−5.8	−14.8	15.0	13	2.0
Nalco Chemical	25⅜	−2.4	−18.8	15.3	14	4.8
National Distillers	35⅝	4.0	−19.7	19.2	16	6.0
Olin	43⅝	35.3	−18.1	46.0	—	3.4
Pennwalt	49½	22.2	−16.1	37.5	—	4.4
Petrolite	23¾	−15.2	−18.1	4.4	14	4.6
PPG Industries	62¼	32.4	−10.4	45.6	13	3.1
Reichhold Chemicals	34¾	−14.5	−17.3	18.3	—	2.3
Rohm & Haas	29¾	30.1	−19.0	45.1	16	2.6
Union Carbide	22⅝	41.4	−11.3	20.7	—	6.6
Witco	33	31.3	−14.3	50.0	13	3.3

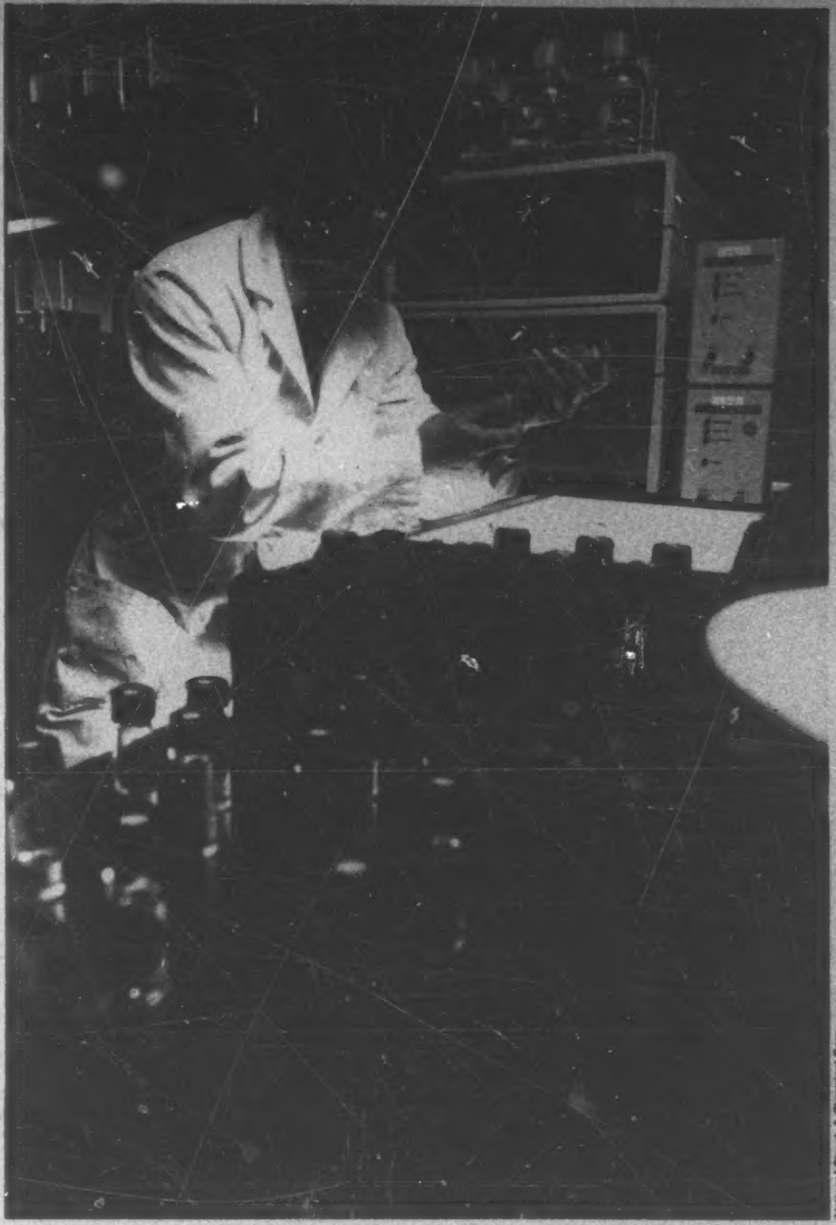
a Based on net earnings including extraordinary and nonrecurring items. Where company showed a loss, no price/earnings ratio is indicated.

SPECIAL REPORT

Spending on research and development in the U.S. is estimated by the National Science Foundation to reach $118.6 billion this year, an increase of 9% over 1985. That's well below the 12% gains racked up in each of the two previous years. In fact, it's the weakest year-to-year increase in the nation's R&D outlays since 1976.

Slower growth in R&D funding for 1986 shows up pretty well across the board, with both government and industry slated to turn in similar increases and both down from their previous pace. Only academia is swimming against the current; universities and colleges are expected to raise their spending a healthy 14%. But academia is a very small source of R&D funds, contributing a mere 2% of the total.

Much of this year's higher R&D spending—close to half—moreover, stems from rising expenditures for defense. Department of Defense funding of R&D is estimated by NSF to reach $37.9 billion in fiscal 1986, 23% more than in the previous fiscal year. This is on the heels of a 22% increase in fiscal 1985. Defense outlays have more than doubled in just five years—whereas nondefense outlays by federal agencies are essentially unchanged—and now account for two thirds of the overall federal R&D budget,



National Starch & Chemical Corp.

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4 Universities and colleges 57

Sources and uses of academic R&D funds. Top spenders on R&D. Demographic trends

Facts & Figures for Chemical R&D

compared with just under half in 1981.

Without defense R&D, federal spending would be down 2% this year. The only major funding agencies other than Defense that have budgeted higher spending on R&D are the National Aeronautics & Space Administration, with outlays expected to be up 14%, and NSF itself, targeted to spend 7% more this year than in fiscal 1985.

Future federal spending on R&D, too, may be adversely affected by the Gramm-Rudman-Hollings Act passed by Congress last December. In an effort to curtail government outlays and thereby eliminate the whopping federal deficit, the law requires that the deficit be reduced by steps year by year until a balanced budget is achieved in fiscal 1991. So far, however, the act has had little direct effect on overall R&D spending, observers say.

Industrial R&D spending is rising more slowly this year, as well, because of the generally sluggish U.S. economy and a heightened cost consciousness on the part of management. Concern about such current uncertainties as the outlook for energy costs, interest rates, and the value of the U.S. dollar also is discouraging some companies from taking a gamble on substantial new R&D projects. Major U.S. chemical companies, as a group, are planning practically no increase in R&D budgets this year, for example.

R&D performance can be seen in considerably better light, though, when the dollar figures are adjusted for cost increases. With inflation waning markedly during the past few years, total spending in real dollars will be up 6% in 1986, NSF estimates. That's not quite the equal of the 7 to 8% gains of the two previous years, but it's double the growth rate in real spending during the decade ending with 1983. Prior to that, real growth in R&D funding had been practically nil for several years.

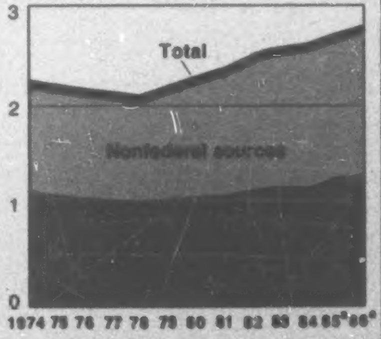
R&D spending now also looks more favorable when stacked up against gross national product, not only because of the growth in scientific efforts in the past few years but because GNP has been expanding in a relatively skimpy fashion recently. NSF figures that total outlays for R&D will be about 2.8% of GNP this year, up slightly from 2.7% in 1985. The percentage has been rising every year since 1978, when it bottomed out at only 2.1% following a long decline from its peak of 3.0% in 1964.

R&D spending relative to GNP is about the same in the U.S. as in West Germany and Japan where, especially in Japan, the percentage also has been growing during the past several years. The U.S. percentage, too, is somewhat higher than the 2.2% level in both the U.K. and France.

But a considerably larger share of the U.S. R&D dollar goes into defense work than is the case with other major industrial nations. Consequently, whereas nondefense outlays for R&D in the U.S. are only 1.9% of GNP, in Japan such outlays are 2.6% and in West Germany 2.5%. Nondefense spending for R&D is 1.8% of GNP for France and 1.6% for the U.K. □

R&D outlays have increased faster than GNP since 1978

R&D spending as % of U.S. gross national product



a Estimated. Source: National Science Foundation

R&D funding continues to expand

With development cutting a bigger piece of the R&D pie, total spending will grow at a relatively low 9% this year

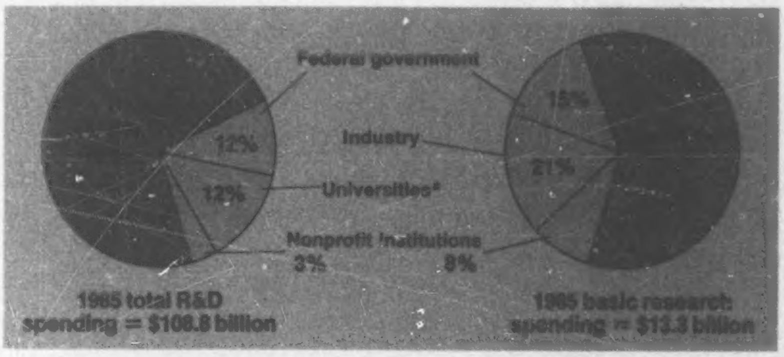
Of the $118.6 billion that will be spent this year on research and development (up 9% from 1985), a hefty 66% will be plowed into development, and 21% will go for applied research and 12% for basic studies. The big D in the R&D picture not only gets the bulk of the funds but it is getting even bigger.

Outlays for development will be up 10% in 1986 and have grown at a 12%-a-year clip during the past decade, while funding of research, up 7% in 1986, has expanded 11% a year since 1976. In that year, 64% of the $39.0 billion devoted to R&D was used for development.

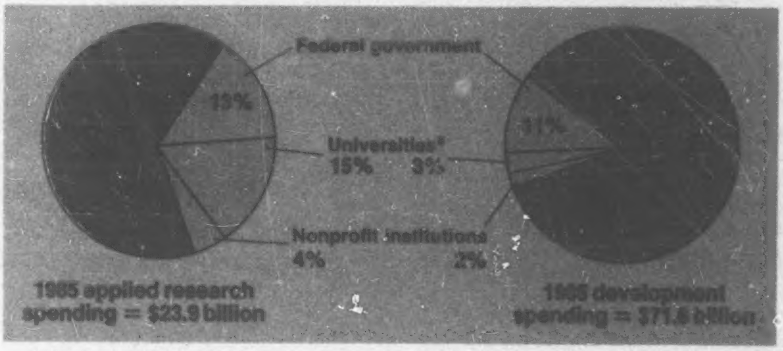
The growth in spending on development partly reflects the growing role of industry in R&D. Industry funds half of U.S. R&D and performs nearly three quarters of it. Industrial R&D has been growing at a rate of 12% a year in the past decade while R&D done elsewhere has been growing at a 10% rate. And 75% of industrial R&D is development.

It also reflects the growing role of defense R&D. Two thirds of federal spending on R&D this year is defense-related, and 90% of that goes into development. Only a third of nondefense federal R&D funds is spent on development.

Industry performs almost three quarters of all R&D, even though universities handle over half of basic research . . .



. . . because company labs do more than two thirds of applied research and a greater share of development



a Includes associated federally funded research and development centers. Source: National Science Foundation

TRENDS IN R&D: Federal share of total spending holds steady during 1980s

% of total outlays	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Federal	47%	47%	47%	47%	46%	46%	47%	49%	50%	50%	51%	51%	51%	53%	56%	56%	57%	58%	61%
Defense related	30	30	29	27	25	23	22	23	24	25	26	26	27	30	32	32	33	34	35
Space related	7	6	6	7	7	7	7	7	7	8	8	8	8	8	9	9	10	11	13
Civilian related	10	11	12	13	14	16	18	19	19	17	17	17	16	15	15	15	14	13	13
Nonfederal	53	53	53	53	54	54	53	51	50	50	49	49	49	47	44	44	43	42	39

a Estimated. Source: National Science Foundation

SOURCES OF R&D FUNDS: Half of the total comes from private industry . . .

$ Billions, current	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Industry	$59.5	$54.4	$48.8	$43.5	$40.1	$35.9	$30.9	$26.1	$22.5	$19.6	$17.7	9%	13%
Federal government	55.2	50.9	45.3	40.7	36.5	33.4	29.5	26.8	23.9	21.6	19.9	9	11
Universities and colleges	2.5	2.2	2.0	1.9	1.7	1.5	1.3	1.2	1.0	0.9	0.8	14	12
Other nonprofit institutions	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.7	0.6	6	9
TOTAL	$118.6	$108.8	$97.3	$87.2	$79.3	$71.8	$62.6	$54.9	$48.1	$42.8	$39.0	9%	12%

a Estimated. Source: National Science Foundation

. . . but universities' contribution, although much smaller, rose most in 1985

$ Billions, constant (1982)	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Industry	$51.7	$48.7	$45.2	$41.9	$40.1	$38.3	$36.1	$33.2	$31.1	$29.2	$28.1	6%	6%
Federal government	47.9	45.6	41.8	39.1	36.5	35.7	34.5	34.3	33.2	32.2	31.8	5	4
Universities and colleges	2.2	2.0	1.8	1.8	1.7	1.6	1.6	1.5	1.4	1.3	1.3	10	5
Other nonprofit institutions	1.2	1.2	1.1	1.1	1.0	1.0	1.0	1.1	1.1	1.0	1.0	0	2
TOTAL	$103.0	$97.4	$89.9	$83.9	$79.3	$76.6	$73.2	$70.1	$66.8	$63.7	$62.2	6%	5%

a Estimated. Source: National Science Foundation

PERFORMERS OF R&D: Government labs' share of total R&D dollars shrinks . . .

$ Billions, current	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Industry	$87.0	$79.5	$71.1	$63.4	$58.0	$51.8	$44.5	$38.2	$33.3	$29.8	$27.0	9%	12%
Federal government	14.0	13.2	11.6	10.6	9.1	8.4	7.6	7.4	6.8	6.0	5.8	6	9
Universities and colleges	10.6	9.5	8.5	7.8	7.3	6.8	6.1	5.4	4.6	4.1	3.7	12	11
Associated FFRDCs[b]	3.6	3.4	3.1	2.7	2.5	2.5	2.2	1.9	1.7	1.4	1.1	6	13
Other nonprofit institutions	3.4	3.3	3.0	2.7	2.4	2.3	2.2	2.0	1.7	1.5	1.4	5	9
TOTAL	$118.6	$108.8	$97.3	$87.2	$79.3	$71.8	$62.6	$54.9	$48.1	$42.8	$39.0	9%	12%

a Estimated. b Federally funded research and development centers administered by universities and colleges. Source: National Science Foundation

. . . as that for academia expands slightly in recent years

$ Billions, constant (1982)	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Industry	$75.5	$71.2	$65.8	$61.0	$58.0	$55.2	$51.9	$48.7	$46.1	$44.3	$42.8	6%	6%
Federal government	12.2	11.8	10.7	10.2	9.1	9.0	9.0	9.5	9.5	9.0	9.3	3	3
Universities and colleges	9.2	8.5	7.8	7.5	7.3	7.3	7.1	6.9	6.5	6.1	6.0	8	4
Associated FFRDCs[b]	3.1	3.0	2.9	2.6	2.5	2.7	2.7	2.5	2.4	2.1	1.8	2	6
Other nonprofit institutions	3.0	3.0	2.7	2.6	2.4	2.4	2.5	2.5	2.3	2.2	2.2	0	3
TOTAL	$103.0	$97.4	$89.9	$83.9	$79.3	$76.6	$73.2	$70.1	$66.8	$63.7	$62.1	6%	5%

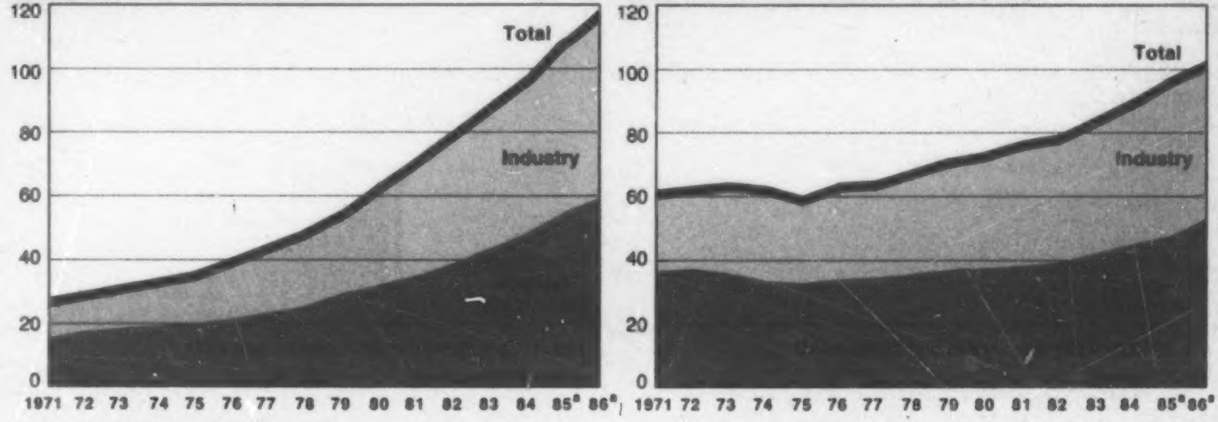
a Estimated. b Federally funded research and development centers administered by universities and colleges. Source: National Science Foundation

Spending for R&D has nearly doubled since 1980 . . .

Sources of R&D funds, $ billions, current

. . . but is up only 40% after adjustment for inflation

Sources of R&D funds, $ billions, constant (1982)



a Estimated. **Source:** National Science Foundation

CHARACTER OF R&D: Development's share of funds is biggest and fastest growing . . .

$ Billions, current	1986ᵃ	1985ᵃ	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Basic research	$14.5	$13.3	$12.1	$11.0	$ 9.9	$ 9.2	$ 8.1	$ 7.3	$ 6.4	$ 5.5	$ 5.0	8%	7%
Applied research	25.3	23.9	22.3	20.4	18.5	16.9	14.1	12.4	10.8	9.7	9.0	6	11
Development	78.9	71.6	62.9	55.8	50.9	45.8	40.5	35.3	30.9	27.5	25.0	10	12

a Estimated. **Source:** National Science Foundation

. . . with outlays expected to expand 6% this year in real dollars

$ Billions, constant (1982)	1986ᵃ	1985ᵃ	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Basic research	$12.6	$11.9	$11.2	$10.6	$ 9.9	$ 9.8	$ 9.5	$ 9.3	$ 8.9	$ 8.3	$ 8.0	5%	5%
Applied research	22.0	21.4	20.6	19.6	18.5	18.0	16.5	15.8	15.1	14.5	14.4	2	4
Development	68.5	64.1	58.1	53.7	50.9	48.8	47.3	45.0	42.8	40.9	39.7	6	6

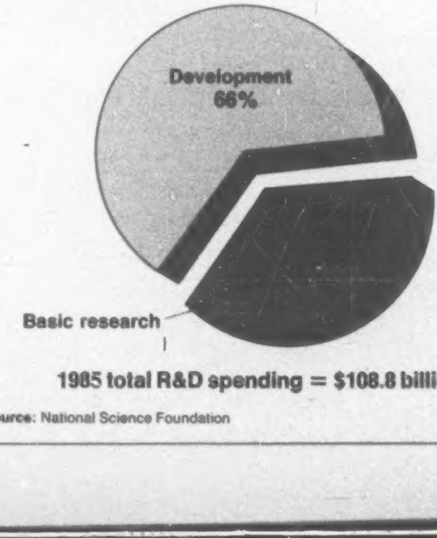
a Estimated. **Source:** National Science Foundation

EMPLOYED SCIENTISTS AND ENGINEERS: Chemists make up 6% of total

	Thousands employed	Per cent
Scientists	**1781.4**	**44.6%**
Physical scientists	254.1	6.4
Chemists	168.6	4.2
Physicists/astronomers	61.2	1.6
Other physical scientists	24.3	0.6
Other scientists	1527.3	38.2
Engineers	**2214.1**	**55.4**
Chemical engineers	140.1	3.5
Other engineers	2074.0	51.9
TOTAL	**3995.5**	**100.0**

Note: 1984 data. **Source:** National Science Foundation

About a third of the R&D dollars goes into research



1985 total R&D spending = $108.8 billion

Source: National Science Foundation

ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS*: Organic chemistry's share has dwindled

% IN EACH GROUP	1985	1984	1983	1982	1981	1980	1979	1978	1977
Biochemistry	40.5%	40.5%	38.3%	39.5%	39.0%	39.8%	38.8%	38.3%	37.9%
Physical, inorganic, and analytical chemistry	29.8	28.8	29.6	28.5	28.0	28.6	28.9	27.4	27.9
Applied chemistry and chemical engineering	18.4	17.6	19.4	19.5	19.1	18.9	19.4	20.8	19.7
Organic chemistry	6.4	7.6	7.3	7.2	8.7	7.4	7.6	8.0	8.8
Macromolecular chemistry	4.9	5.5	5.4	5.3	5.2	5.3	5.3	5.5	5.7

% OF ALL BIOCHEMISTRY ABSTRACTS	1985	1984	1983	1982	1981	1980	1979	1978	1977
Mammalian hormones[a]	12.3%	12.4%	12.9%	12.2%	6.8%	6.0%	5.9%	5.9%	5.5%
Pharmacology	12.3	11.6	11.8	12.0	12.4	12.0	11.9	12.3	12.0
Mammalian biochemistry[a]	11.1	11.3	11.1	11.6	15.6	16.3	17.1	17.2	17.7
Toxicology	7.9	8.0	8.5	8.1	8.7	8.3	7.4	7.5	6.2
Microbial biochemistry[a]	5.7	5.2	5.1	5.3	5.6	5.2	5.3	5.1	5.3
Enzymes	5.6	5.8	6.1	5.9	5.9	6.2	6.4	5.7	6.1
Plant biochemistry[a]	5.5	6.2	5.9	6.2	5.8	5.7	5.8	5.4	5.8
Immunochemistry	5.3	4.8	4.2	4.4	3.4	3.1	3.2	3.6	3.1
Biochemical genetics[b]	5.2	4.2	3.8	3.3	—	—	—	—	—
Biochemical methods	4.9	4.9	4.9	4.6	5.7	5.5	5.4	4.6	5.1
General biochemistry	4.9	5.3	5.8	6.0	7.5	6.6	7.0	6.5	7.0
Others	19.3	20.3	19.9	20.4	22.6	25.1	24.6	26.2	26.2

% OF ALL PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY ABSTRACTS	1985	1984	1983	1982	1981	1980	1979	1978	1977
Nuclear chemistry	21.8%	22.2%	22.5%	22.6%	21.6%	23.2%	25.1%	20.7%	21.1%
Spectra	18.4	18.0	17.6	17.2	18.0	18.2	17.0	17.0	18.1
Electric phenomena	10.8	10.8	10.0	10.5	11.0	11.2	11.4	10.9	10.5
Crystallography and liquid crystals	7.5	7.8	8.3	8.7	8.9	8.1	8.2	9.2	8.9
General physical chemistry	6.9	6.9	7.3	7.3	7.2	7.1	6.6	6.6	6.8
Analytical chemistry	6.1	6.3	6.2	5.4	5.8	5.6	5.6	7.2	5.8
Others	28.5	28.0	28.1	28.3	27.5	26.6	25.8	28.4	28.8

% OF ALL APPLIED CHEMISTRY AND CHEMICAL ENGINEERING ABSTRACTS	1985	1984	1983	1982	1981	1980	1979	1978	1977
Water, wastes, and pollution	20.2%	21.0%	19.6%	21.7%	24.0%	22.5%	20.8%	20.8%	23.2%
Metals and alloys	20.0	18.9	19.1	22.2	17.9	22.0	23.6	24.0	24.2
Mineralogical and geological chemistry	12.5	14.6	14.1	13.6	14.1	15.7	15.8	16.8	13.4
Fossil fuels, derivatives, and related products	10.1	10.1	10.3	9.4	9.4	8.9	7.8	8.2	9.2
Unit operations and processes	7.5	7.0	7.5	6.9	6.4	6.0	6.1	6.4	5.8
Others	29.7	28.4	29.4	26.2	28.2	24.9	25.9	23.8	24.2

% OF ALL ORGANIC CHEMISTRY ABSTRACTS	1985	1984	1983	1982	1981	1980	1979	1978	1977
Physical organic chemistry	30.6%	32.0%	30.5%	31.5%	37.0%	38.8%	38.8%	36.8%	41.3%
Organometallic and organometalloidal compounds[a]	16.2	17.1	16.3	14.8	8.3	8.2	8.5	8.9	8.5
Heterocyclic compounds[a]	16.1	15.6	16.2	15.6	18.2	17.3	16.0	17.5	17.0
Aromatic compounds[a]	6.3	6.3	7.1	7.2	8.7	7.8	8.2	8.6	8.5
Carbohydrates	5.7	5.7	5.8	5.8	5.4	5.7	6.0	5.2	4.6
Biomolecules and their synthetic analogs[b]	4.9	4.4	4.5	3.7	—	—	—	—	—
Amino acids, peptides, and proteins[a]	4.6	4.8	4.5	4.4	4.2	3.7	4.1	4.0	3.7
Aliphatic compounds[a]	4.2	3.6	4.3	5.2	6.6	6.0	6.0	6.9	5.9
Others	11.4	10.5	10.8	11.8	11.6	12.5	12.4	12.1	10.5

% OF ALL MACROMOLECULAR CHEMISTRY ABSTRACTS	1985	1984	1983	1982	1981	1980	1979	1978	1977
Synthetic high polymers	34.1%	34.0%	34.4%	34.7%	30.3%	27.0%	26.3%	25.6%	26.5%
Plastics manufacture and uses	25.3	24.2	24.4	21.9	26.4	28.1	27.8	28.1	27.5
Cellulose, lignin, paper, and other wood products	9.1	9.6	9.1	9.7	10.1	10.9	11.1	10.6	10.0
Textiles	8.2	7.3	7.9	8.9	9.9	10.1	10.1	12.1	11.0
Coatings, inks, and related products	7.2	7.8	6.6	7.6	7.5	7.4	8.1	7.5	7.5
Synthetic elastomers and natural rubber	6.8	7.3	7.5	7.8	7.9	8.4	7.6	8.0	8.5
Others	9.3	9.8	10.1	9.4	7.9	8.1	9.0	8.1	9.0

a Definition of section content changed in 1982. b New section in 1982. Source: Chemical Abstracts Service

U.S. PATENTS: Percentage granted to foreign residents reaches all-time high

	1985	1984	1983	1982	1981	1980	1979[a]	1978	1977	1976	1975
U.S.[b]	39,554	38,364	32,871	33,896	39,223	37,356	30,081	41,254	41,485	44,280	46,717
Foreign[c]	32,107	28,837	23,989	23,993	26,548	24,463	18,773	24,848	23,784	25,946	25,285
TOTAL	**71,661**	**67,201**	**56,860**	**57,889**	**65,771**	**61,819**	**48,854**	**66,102**	**65,269**	**70,226**	**72,002**
% Foreign	**44.8%**	**42.9%**	**42.2%**	**41.4%**	**40.4%**	**39.6%**	**38.4%**	**37.6%**	**36.4%**	**36.9%**	**35.1%**

a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents it might otherwise have issued. b U.S. patents granted to U.S. residents. c U.S. patents granted to residents of foreign countries. Source: U.S. Patent & Trademark Office

Outlays rise only because of military work

FEDERAL OBLIGATIONS FOR R&D: Defense spending will rise 23% in 1986

Department or agency	Total R&D ($ millions) 1986[a]	1985[a]	1984	1983	1982
Agriculture	$ 882.1	$ 939.1	$ 866.2	$ 847.6	$ 797.3
Agricultural Research Service	468.5	470.9	451.3	443.4	404.9
Cooperative State Research Service	239.2	274.3	235.7	232.3	219.0
Forest Service	104.2	121.0	108.4	107.7	112.1
Commerce	274.7	381.4	358.2	335.0	336.3
National Bureau of Standards	89.4	101.2	95.5	95.0	88.8
National Oceanic & Atmospheric Administration	171.0	261.9	244.3	222.0	222.0
Defense	37,932.5	30,958.5	25,372.9	22,992.8	20,622.6
Air Force	15,957.8	14,207.2	12,091.6	10,812.6	9,357.9
Army	5,445.7	4,636.6	4,225.5	3,998.1	3,760.5
Navy	11,283.8	9,316.8	7,605.6	6,068.2	5,845.1
Defense agencies[b]	5,153.0	2,746.1	1,391.5	2,052.3	1,618.1
Energy	4,593.5	4,848.3	4,673.6	4,536.7	4,708.2
Environmental Protection Agency	330.6	312.4	261.2	240.7	335.1
Health & Human Services	5,142.5	5,454.2	4,830.7	4,352.5	3,940.7
National Institutes of Health	4,560.0	4,835.9	4,257.4	3,789.2	3,433.1
Interior	368.2	410.9	410.9	382.5	381.1
Geological Survey	212.6	213.8	208.9	157.0	152.6
National Aeronautics & Space Administration	3,753.3	3,297.3	2,821.9	2,661.6	3,077.9
National Science Foundation	1,444.6	1,353.1	1,202.8	1,062.0	975.3
Tennessee Valley Authority	67.9	83.3	68.1	63.0	65.0
Others	1,223.4	1,413.5	1,358.4	1,237.1	1,173.1
TOTAL	$56,013.3	$49,452.0	$42,224.9	$38,711.5	$36,432.6

a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Note. Fiscal years. Source: National Science Foundation

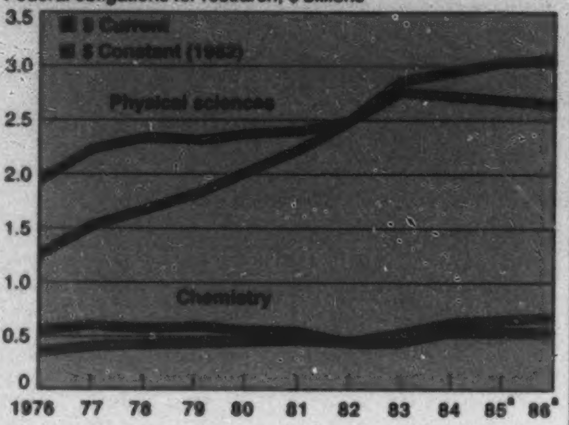
FEDERAL OBLIGATIONS FOR RESEARCH: Basic research gains modestly as applied declines

Department or agency, $ millions	1986[a] Basic research	1986[a] Applied research	1985[a] Basic research	1985[a] Applied research	1984 Basic research	1984 Applied research	1983 Basic research	1983 Applied research	1982 Basic research	1982 Applied research
Agriculture	$ 418.5	$ 433.0	$ 440.3	$ 466.6	$ 392.6	$ 442.2	$ 382.0	$ 455.5	$ 330.8	$ 435.7
Agricultural Research Service	250.6	190.5	250.6	192.4	240.6	183.7	215.3	202.6	192.9	186.2
Cooperative State Research Service	119.3	119.9	132.0	142.3	99.6	136.2	98.8	133.5	91.3	127.7
Forest Service	40.3	60.9	47.2	70.2	41.2	63.9	38.8	65.1	38.7	69.0
Commerce	17.5	210.0	21.2	290.9	20.6	276.1	19.2	265.6	16.9	259.2
National Bureau of Standards	17.1	63.7	20.0	67.3	20.2	63.5	18.4	63.1	16.5	57.4
National Oceanic & Atmospheric Administration	0	136.2	0	210.2	0	197.7	0	188.9	0	188.5
Defense	964.4	2529.0	830.0	2226.8	847.9	2200.7	785.6	2437.0	686.7	2266.1
Air Force	228.6	591.5	195.4	523.1	192.4	547.7	164.2	524.2	145.8	488.1
Army	267.2	619.1	217.5	507.1	222.1	486.7	208.3	485.3	167.7	451.6
Navy	371.6	481.3	332.3	430.2	315.8	449.6	305.4	521.6	200.3	498.4
Defense agencies[b]	97.1	837.2	84.8	766.2	117.6	716.6	107.7	905.9	72.9	828.1
Energy	937.8	1019.8	915.5	1222.9	830.4	1194.5	767.7	1193.4	642.2	1053.9
Environmental Protection Agency	40.2	170.5	36.6	168.9	29.6	142.3	22.2	152.4	32.7	210.7
Health & Human Services	3055.6	1697.0	3229.9	1809.3	2814.5	1651.5	2475.4	1545.4	2144.7	1460.9
National Institutes of Health	2844.8	1341.3	3021.8	1422.5	2624.8	1285.6	2313.0	1165.2	2020.7	1103.8
Interior	117.7	230.0	137.0	252.9	125.9	254.3	103.0	254.7	76.5	275.0
Geological Survey	81.5	123.5	80.1	129.3	78.9	125.1	64.7	89.9	52.6	99.4
National Aeronautics & Space Administration	835.0	814.2	775.8	846.4	754.5	954.7	617.0	927.8	535.7	971.4
National Science Foundation	1364.9	79.7	1272.8	80.3	1132.3	70.5	999.1	62.9	916.1	57.1
Tennessee Valley Authority	4.7	8.3	5.8	10.0	5.1	9.2	5.6	6.7	4.6	6.1
Others	118.8	651.2	122.0	725.6	114.0	715.4	103.3	692.0	94.7	642.5
TOTAL	$7875.1	$7842.7	$7786.9	$8100.4	$7067.4	$7911.4	$6260.1	$7993.4	$5481.6	$7540.6

a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Note: Fiscal years. Source: National Science Foundation

Federal outlays for chemistry in constant dollars have held steady since 1984

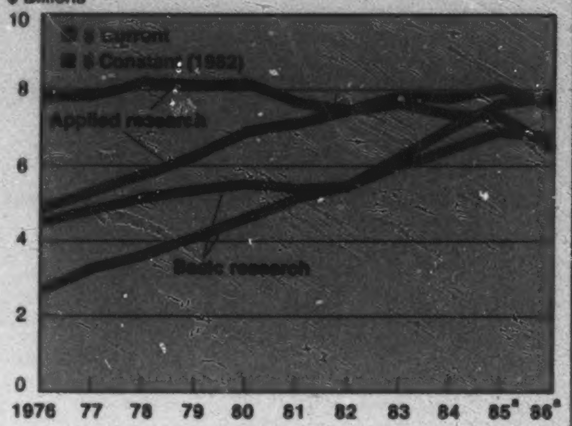
Federal obligations for research, $ billions



a Estimated. Note: Fiscal years. Source: National Science Foundation

Government support for basic research tops spending on applied research

$ Billions



a Estimated. Note: Fiscal years. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Research spending drops 1% in 1986

$ Millions for research only	1986[a]	1985[a]	1984	1983	1982	1981	Annual change 1985–86	Annual change 1981–86
Engineering	$ 3,537.6	$ 3,503.8	$ 3,624.1	$ 3,517.0	$ 3,286.5	$ 3,071.5	1%	3%
Chemical	136.8	152.4	144.5	145.0	95.1	147.6	−10	−2
Metallurgy and materials	375.7	365.9	341.1	332.5	309.1	256.0	3	8
Environmental sciences	1,315.8	1,358.1	1,275.9	1,251.2	1,148.3	1,121.1	−3	3
Life sciences	6,039.9	6,291.8	5,635.9	5,177.9	4,745.5	4,435.6	−4	6
Mathematics and computer sciences	635.3	579.0	440.3	419.4	350.1	278.9	8	18
Physical sciences	3,040.1	3,036.4	2,969.0	2,891.4	2,500.4	2,220.5	0	6
Chemistry	622.7	611.3	606.4	520.3	481.2	486.9	2	5
Physics	1,822.8	1,848.5	1,836.4	1,854.6	1,610.5	1,345.6	−1	6
Other sciences	1,149.1	1,118.2	1,033.6	996.6	891.4	1,085.2	3	1
TOTAL	$15,717.8	$15,887.3	$14,978.8	$14,253.5	$13,022.2	$12,212.8	−1%	5%

a Estimated. Note: Fisc[illegible] years. [illegible]rce: National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Defense accounts for most growth this year

Department or agency	Development ($ millions) 1986[a]	1985[a]	1984	1983	1982
Agriculture	$ 30.6	$ 32.3	$ 31.3	$ 30.0	$ 30.8
Agricultural Research Service	27.4	27.9	27.0	25.5	25.8
Cooperative State Research Service	0	0	0	0	0
Forest Service	3.0	3.6	3.3	3.6	4.5
Commerce	47.2	69.3	61.5	50.2	60.2
National Bureau of Standards	8.6	14.0	11.8	13.6	14.9
National Oceanic & Atmospheric Administration	34.8	51.7	46.6	33.1	33.5
Defense	34,439.0	27,901.9	22,324.3	19,770.1	17,889.8
Air Force	15,137.5	13,488.7	11,351.5	10,124.2	8,724.0
Army	4,559.4	3,911.9	3,516.8	3,314.5	3,121.3
Navy	10,431.0	8,554.3	6,840.2	5,241.2	5,066.4
Defense agencies[b]	4,218.7	1,895.1	557.3	1,038.7	717.1
Energy	2,635.9	2,709.9	2,848.7	2,575.6	3,012.1
Environmental Protection Agency	119.9	106.9	89.2	66.1	91.7
Health & Human Services	389.9	415.1	364.7	331.7	335.2
National Institutes of Health	373.8	391.6	347.0	311.0	308.7
Interior	20.4	21.1	30.7	24.8	29.8
Geological Survey	7.6	4.5	4.9	2.3	0.5
National Aeronautics & Space Administration	2,104.1	1,675.1	1,112.7	1,116.8	1,670.7
National Science Foundation	0	0	0	0	2.2
Tennessee Valley Authority	55.0	67.6	53.8	50.7	72.3
Others	453.5	565.5	529.2	442.0	435.8
TOTAL	$40,295.5	$33,564.7	$27,248.1	$24,458.0	$23,410.4

a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Note: Fiscal years. Source: National Science Foundation

BASIC RESEARCH: Funding for chemistry is expected to rise 3% this year

	Federal obligations ($ millions)									
	1986[a]		1985[a]		1984		1983		1982	
Department or agency	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Agriculture	$ 46.5	$ 44.6	$ 47.5	$ 45.5	$ 45.4	$ 43.5	$ 40.0	$ 38.2	$ 36.2	$ 34.5
Agricultural Research Service	38.9	37.5	38.9	37.5	37.4	36.0	33.5	32.2	30.0	28.9
Cooperative State Research Service	5.0	5.0	5.6	5.6	5.4	5.4	4.1	4.1	3.8	3.8
Forest Service	2.6	2.1	3.0	2.4	2.6	2.1	2.4	1.9	2.4	1.8
Commerce	15.1	5.3	17.7	6.9	16.3	4.8	15.7	4.7	13.7	4.2
National Bureau of Standards	15.1	5.3	17.1	6.2	16.3	4.8	15.7	4.6	13.7	4.2
Defense	240.4	72.2	215.2	63.1	212.2	60.0	198.4	55.6	188.7	51.5
Air Force	59.4	25.8	52.8	22.0	48.3	20.3	39.3	17.5	34.2	13.9
Army	67.4	21.7	58.4	18.2	59.8	19.1	58.7	19.4	59.6	20.0
Navy	112.7	24.8	100.7	22.9	100.4	20.7	98.0	18.7	93.1	17.7
Defense agencies[b]	0.9	0	3.3	0	3.7	0	2.5	0	1.8	0
Energy	773.1	91.7	748.7	91.3	688.4	108.4	639.2	104.3	530.8	75.5
Environmental Protection Agency	6.2	6.2	5.8	5.8	3.0	3.0	2.3	1.9	3.8	3.5
Health & Human Services	78.8	71.1	83.4	75.3	72.0	65.0	61.8	55.0	53.2	48.0
National Institutes of Health	76.8	69.1	81.5	73.4	70.8	63.8	60.9	54.2	52.9	47.7
Interior	7.6	6.0	7.6	6.0	7.1	5.6	2.9	1.8	8.1	2.5
Geological Survey	7.5	5.9	7.5	6.0	7.1	5.6	2.6	1.8	2.8	1.9
National Aeronautics & Space Administration	433.6	8.4	371.8	7.1	338.7	5.4	329.5	7.7	280.6	5.2
National Science Foundation	388.1	126.8	368.0	119.4	330.2	106.8	283.5	88.5	266.6	83.3
Tennessee Valley Authority	2.7	0	4.0	0	3.7	0	3.5	3.5	3.0	3.0
Others	11.1	0.3	12.1	0.4	11.0	0.9	10.4	1.0	9.1	0.8
TOTAL	$2003.2	$432.6	$1881.8	$420.8	$1728.0	$403.4	$1587.2	$362.2	$1393.8	$312.0

a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Note:** Fiscal years. **Source:** National Science Foundation

APPLIED RESEARCH: Chemical work stresses defense, agriculture, and health

	Federal obligations ($ millions)									
	1986[a]		1985[a]		1984		1983		1982	
Department or agency	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Agriculture	$ 27.0	$ 25.1	$ 28.6	$ 26.6	$ 27.3	$ 25.5	$ 27.6	$ 25.6	$ 26.0	$ 24.0
Agricultural Research Service	17.5	16.2	17.7	16.4	16.9	15.6	18.6	17.2	17.1	15.8
Cooperative State Research Service	7.2	7.2	8.3	8.3	8.1	8.1	6.7	6.7	6.4	6.4
Forest Service	2.3	1.7	2.7	2.0	2.4	1.8	2.3	1.7	2.6	1.7
Commerce	36.3	11.5	37.1	11.2	36.9	10.5	33.9	9.3	32.6	8.8
National Bureau of Standards	28.1	10.4	26.3	9.2	28.1	9.3	26.7	8.1	25.4	7.3
Defense	396.8	87.6	395.1	74.8	477.2	79.8	562.0	66.3	500.0	66.6
Air Force	62.1	17.9	54.9	15.8	58.6	16.4	54.5	13.7	50.5	13.3
Army	117.5	56.0	100.7	46.9	77.4	47.2	86.9	39.9	83.2	41.4
Navy	71.5	13.4	62.6	11.6	69.2	15.9	135.2	12.3	128.7	11.7
Defense agencies[b]	145.7	0.4	176.8	0.4	272.1	0.3	285.4	0.3	237.6	0.3
Energy	477.6	9.3	596.2	18.1	603.5	32.0	584.8	13.3	482.8	29.9
Environmental Protection Agency	11.6	11.6	13.8	13.8	13.8	12.9	13.9	12.8	16.6	15.3
Health & Human Services	26.7	23.1	28.0	24.3	24.7	21.3	22.6	19.2	17.6	15.3
National Institutes of Health	24.7	21.1	26.1	22.4	23.6	20.3	21.5	18.1	17.2	14.9
Interior	15.9	13.3	16.1	13.7	15.7	13.6	5.5	4.4	10.2	3.7
Geological Survey	15.0	13.0	15.4	13.3	14.9	12.8	4.7	3.8	4.0	3.2
National Aeronautics & Space Administration	26.4	3.2	21.1	2.2	25.6	1.9	40.4	1.7	8.9	1.0
National Science Foundation	14.8	4.6	13.9	4.3	10.9	3.1	9.4	3.9	6.0	2.8
Others	3.9	0.8	4.6	1.5	5.4	2.4	4.2	1.6	5.8	1.8
TOTAL	$1037.0	$190.1	$1154.5	$190.5	$1241.0	$203.0	$1304.3	$158.1	$1106.5	$169.2

a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Note:** Fiscal years. **Source:** National Science Foundation

OBLIGATIONS FOR ENGINEERING RESEARCH: Support for chemical engineering declines

	Federal obligations ($ millions)									
	1986[a]		1985[a]		1984		1983		1982	
Department or agency	Engineering	Chemical engineering	Engineering	Chemical engineering	Engineering	Chemical engineering	Engineering	Chemical engineering	Engineering	Chemical engineering
Agriculture	$ 57.0	$ 6.4	$ 59.4	$ 6.9	$ 56.7	$ 6.4	$ 54.7	$ 6.2	$ 51.2	$ 5.8
Agricultural Research Service	33.4	3.3	33.6	3.3	32.2	3.2	32.9	3.2	30.0	2.9
Cooperative State Research Service	9.8	0	9.7	0	10.2	0	7.4	0	6.9	0
Forest Service	13.8	3.1	16.0	3.6	14.3	3.1	14.4	3.0	14.2	2.9
Commerce	33.8	1.4	39.0	1.5	35.3	1.8	37.4	1.3	32.0	2.0
National Bureau of Standards	28.6	1.4	32.2	1.5	28.0	1.8	29.4	1.3	23.8	2.0
Defense	1609.6	39.3	1448.8	35.3	1488.4	38.4	1573.9	44.9	1473.3	39.0
Air Force	481.7	3.4	423.8	2.1	439.5	3.5	419.3	3.1	387.3	2.9
Army	398.0	24.7	320.6	21.3	324.8	23.5	318.9	29.3	297.2	24.4
Navy	425.8	11.2	377.9	11.8	398.4	11.3	395.5	11.9	378.0	11.6
Defense agencies[b]	304.1	0	326.5	0.1	325.7	0.2	440.2	0.6	410.8	0.2
Energy	406.6	32.3	462.2	46.1	439.0	46.1	440.2	51.9	420.8	1.1
Environmental Protection Agency	41.5	15.8	50.7	23.3	37.6	17.8	47.8	16.7	76.4	26.0
Health & Human Services	54.1	0	57.4	0	50.9	0	39.7	0	41.4	0
National Institutes of Health	53.9	0	57.2	0	50.7	0	39.7	0	41.4	0
Interior	70.9	4.7	106.4	4.7	111.4	4.5	91.4	0.4	87.1	1.4
Geological Survey	6.6	4.2	7.1	4.2	8.0	4.1	5.7	0	8.2	0.2
National Aeronautics & Space Administration	843.7	0.4	845.5	0.3	967.8	0.3	799.6	1.0	771.7	0.4
National Science Foundation	214.5	35.4	195.1	32.9	164.9	27.7	142.5	21.5	129.9	18.8
Others	203.9	1.1	239.3	1.4	271.9	1.5	286.6	1.1	297.6	0.6
TOTAL	$3537.6	$136.8	$3503.8	$152.4	$3624.1	$144.5	$3517.0	$145.0	$3386.5	$95.1

a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Note: Fiscal years. Source: National Science Foundation

UNIVERSITY RESEARCH: Chemistry's share of government funds is nearly unchanged

								Annual change	
Federal obligations, $ millions	1986[a]	1985[a]	1984	1983	1982	1981	1980	1985–86	1980–86
Engineering	$ 566.8	$ 521.2	$ 474.2	$ 408.7	$ 361.5	$ 365.3	$ 323.7	9%	10%
Chemical	53.1	55.9	51.2	23.6	19.4	21.9	20.3	−5	17
Metallurgy and materials	105.8	98.2	87.7	86.0	75.3	69.5	57.3	8	11
Environmental sciences	364.4	340.7	319.5	316.9	274.7	280.3	297.0	7	3
Life sciences	3055.6	3221.4	2600.2	2460.0	2205.0	2117.2	1984.7	−5	7
Mathematics and computer sciences	288.3	250.2	181.6	172.4	139.7	121.4	94.6	15	20
Physical sciences	829.2	784.0	697.8	596.5	559.1	525.2	461.0	6	10
Chemistry	276.0	276.7	242.3	205.7	189.6	193.5	159.5	0	10
Physics	433.5	408.9	375.2	328.8	306.0	274.5	246.1	6	10
Other sciences	317.2	338.9	304.1	297.8	255.7	297.5	302.7	−6	1
TOTAL	$5421.5	$5456.4	$4777.4	$4252.3	$3795.7	$3706.9	$3463.6	−1%	8%

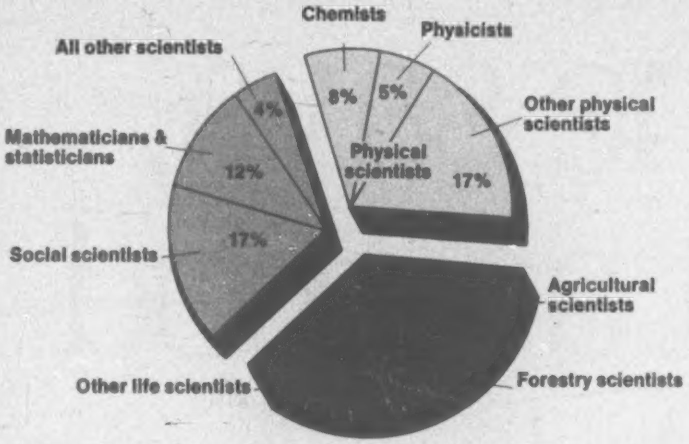
a Estimated. Note: Fiscal years. Source: National Science Foundation

UNIVERSITY BASIC RESEARCH: Basic chemistry gains slightly higher federal support

								Annual change	
Federal obligations, $ millions	1986[a]	1985[a]	1984	1983	1982	1981	1980	1985–86	1980–86
Engineering	$ 418.8	$ 377.6	$ 340.3	$ 295.5	$ 259.0	$ 237.3	$ 208.4	11%	12%
Chemical	34.9	33.5	29.6	18.9	16.6	19.8	16.9	4	13
Metallurgy and materials	93.5	85.4	79.9	76.8	69.6	62.6	51.9	9	10
Environmental sciences	330.5	308.9	286.9	284.3	256.0	241.6	255.3	7	4
Life sciences	2210.1	2313.3	1979.8	1701.7	1483.7	1314.6	1219.5	−4	10
Mathematics and computer sciences	189.1	164.5	152.6	146.8	118.8	102.6	79.8	15	15
Physical sciences	701.1	656.8	581.9	502.2	455.3	434.7	375.9	7	11
Chemistry	246.4	237.0	212.1	181.9	165.3	164.7	136.1	4	10
Physics	343.8	326.7	293.9	264.7	238.6	222.4	194.3	5	10
Other sciences	164.9	164.5	147.4	147.2	120.5	148.2	152.4	0	1
TOTAL	$4014.5	$3985.6	$3490.7	$3077.7	$2683.3	$2479.0	$2291.3	1%	10%

a Estimated. Note: Fiscal years. Source: National Science Foundation

About 8% of government scientists are chemists



1985 total federal scientists = 91,408[a]

[a] As of October 1985; does not include computer specialists. Source: National Science Foundation

SCIENTISTS AND ENGINEERS BY AGENCY: Half work for Defense Department

Department or agency	Physical scientists	Chemists	Physicists	Engineers	Chemical engineers	Other scientists[a]	Total scientists and engineers[a]
Agriculture	1,504	887	23	2,915	55	25,524	29,943
Commerce	3,714	319	525	761	35	4,570	9,045
Defense	9,171	2086	3160	70,772	1023	39,491	119,434
Air Force	1,090	313	446	12,044	78	6,030	19,164
Army	3,191	918	759	24,899	513	14,189	42,279
Navy	4,068	764	1932	32,117	414	12,012	48,197
Others	822	91	23	1,712	18	7,260	9,794
Energy	741	167	95	2,711	133	905	4,357
Environmental Protection Agency	1,828	599	17	1,946	162	1,226	5,000
Health & Human Services	2,152	2002	66	349	16	7,175	9,676
Interior	5,166	429	41	3,138	95	7,762	16,066
National Aeronautics & Space Administration	1,131	27	242	9,363	50	841	11,335
Tennessee Valley Authority	200	94	0	3,541	175	658	4,399
Transportation	91	26	5	4,495	11	1,480	6,066
Veterans Administration	586	499	43	1,115	0	3,642	5,343
Others	1,319	454	53	3,987	41	12,071	17,377
TOTAL	27,603	7589	4290	105,093	1796	105,345	238,041

a Includes computer specialists. Note: Data as of October 1985. Source: National Science Foundation

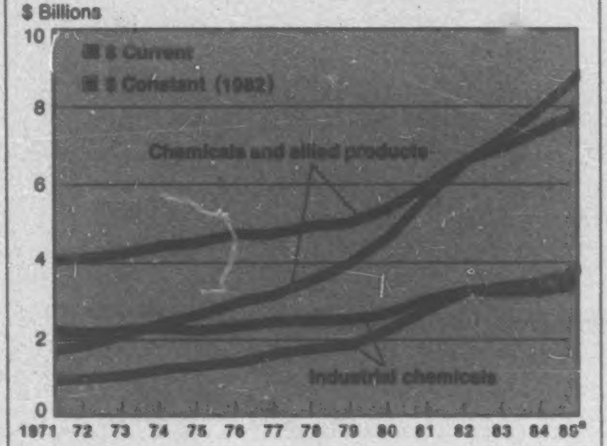
FEDERAL SCIENTISTS AND ENGINEERS: Number of chemists has fallen from 1978 peak

Thousands	1985	1984	1983	1981	1980	1979	1978	1977	1976	1975	1974	1973
Physical scientists	27.6	26.5	27.1	27.4	27.6	27.6	27.5	27.1	27.1	26.7	26.3	26.4
Chemists	7.6	7.6	7.7	7.9	8.1	8.1	8.3	8.0	8.1	8.0	7.8	8.0
Physicists	4.3	4.3	4.4	4.5	4.6	4.9	5.0	5.1	5.3	5.4	5.5	5.6
Engineers	105.1	99.1	94.3	90.9	89.6	88.8	89.2	87.8	87.0	86.6	82.5	84.3
Chemical	1.8	1.7	1.5	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.5
Computer specialists	41.5	38.2	35.2	na	na	na	na	na	na	na	na	na
Other scientists	63.8	62.7	62.3	59.3	60.8	58.3	57.2	54.3	51.6	50.6	48.8	48.4
TOTAL	238.0	226.5	218.9	177.5	178.0	174.7	173.9	169.2	165.7	163.9	157.6	159.1

Note. As of October of each year. Includes computer specialists. No data for 1982. na = not available. Source: National Science Foundation

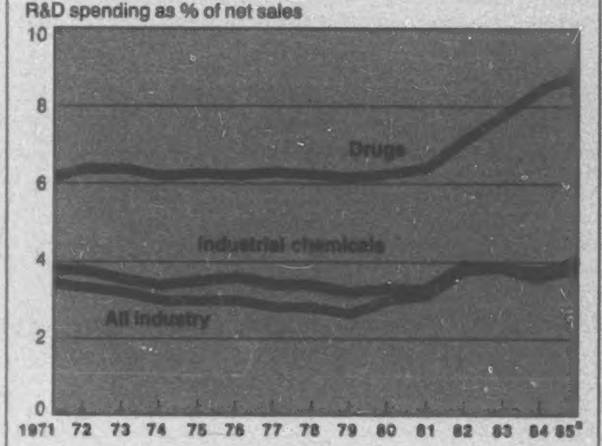
Growth eases a bit for industrial R&D

R&D spending by chemical companies is higher in both current and real dollars



a C&EN estimates. Source: National Science Foundation

R&D spending has been gaining a larger share of industry's revenues



a C&EN estimates. Source: National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Chemical producers increase their spending 11%

$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	$ 8,900a	$ 8,024	$ 7,293	$ 6,659	$ 5,625	$ 4,636	$ 4,038	$ 3,580	$ 3,202	$ 3,017	$ 2,727	11%	13%
Industrial chemicals	3,950a	3,546	3,411	3,301	2,802	2,197	1,962	1,798	1,668	1,524	1,391	11	11
Drugs	4,950a	4,476	3,882	3,358	2,823	1,777	1,517	1,308	1,117	1,091	981	11	14
Other chemicals						662	559	474	417	401	354		
Other industries	70,600a	63,643	56,110	51,337	46,185	39,869	34,188	29,724	26,623	23,980	21,460	11	13
TOTAL	$79,500	$71,667	$63,403	$57,996	$51,810	$44,505	$38,226	$33,304	$29,825	$26,997	$24,187	11%	13%

a C&EN estimates. Source: National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Industry pumps more of its own money into R&D

$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	$ 8,650a	$ 7,802	$ 6,845	$ 6,226	$ 5,205	$ 4,264	$ 3,692	$ 3,250	$ 2,907	$ 2,751	$ 2,490	11%	13%
Industrial chemicals	3,710a	3,334	2,970	2,879	2,393	1,856	1,617	1,473	1,387	1,275	1,173	11	12
Drugs	3,785a	3,401	2,937	2,490	2,064	1,755	2,075	1,777	1,520	1,476	1,317	11	14
Other chemicals	1,155a	1,066	938	856	747	653							
Other industries	44,850a	40,803	36,016	33,286	30,223	26,212	22,016	18,865	16,433	14,685	13,092	10	13
TOTAL	$53,500	$48,605	$42,861	$39,512	$35,428	$30,476	$25,708	$22,115	$19,340	$17,436	$15,582	10%	13%

a C&EN estimates. Source: National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Only 1% goes to the chemical industry

$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	$ 250[a]	$ 222[b]	$ 448	$ 434	$ 421	$ 372	$ 346	$ 330	$ 295	$ 266	$ 236	13%	1%
Industrial chemicals	240[a]	213[b]	440	423	409	341	345	325	281	249	218	13	1
Drugs and other chemicals	10[a]	9	8	11	12	31	1	5	14	17	18	11	−5
Other industries	25,750	22,850	20,094	18,049	15,961	13,657	12,172	10,859	10,190	9,295	8369	13	12
TOTAL	$26,000	$23,072	$20,542	$18,483	$16,382	$14,025	$12,518	$11,189	$10,485	$9,561	$8605	13%	12%

a C&EN estimates. b The decline in 1984 from 1983 results from a change in the administration of federally funded Oak Ridge National Laboratory from a chemical company to a company in the aircraft and missiles industry. Source: National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Chemical companies boost spending outside U.S.

$ Millions	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	$ 800	$ 760	$ 732	$ 684	$ 715	$ 603	$ 500	$ 395	$ 332	$ 312	$ 269	5%	12%
Industrial and other chemicals	380	357	354	313	287	245	199	151	133	108	85	6	16
Drugs	420	403	378	371	428	357	301	244	199	204	184	4	9
Other industries	3000	2775	2544	2413	2679	2562	2254	1814	1545	1347	1185	8	10
TOTAL	$3800	$3535	$3276	$3098	$3393	$3165	$2754	$2209	$1877	$1659	$1454	7%	10

a C&EN estimates. Source: National Science Foundation

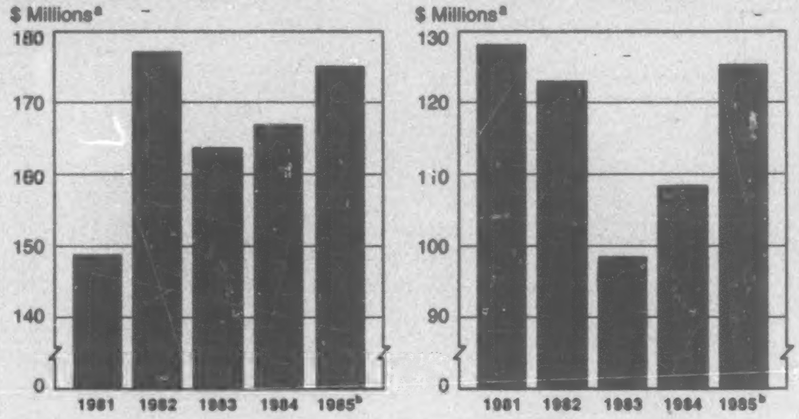
CHEMICAL R&D SPENDING: Budget cuts balance increases among major companies

$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Air Products	$ 60	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19
American Cyanamid	265	251	232	208	185	166	148	130	108	96	83
Celanese	105	103	94	85	100	104	94	92	83	77	70
Dow Chemical	600	547	507	492	460	404	314	269	232	203	188
Du Pont[b]	1030	1080	1000	875	775	647	591	509	461	367	353
Ethyl	47	47	40	39	39	37	34	29	25	28	25
W. R. Grace	100	92	81	73	64	57	45	42	37	32	28
Hercules	69	76	72	74	74	65	57	50	43	40	37
Monsanto	520	470	370	290	264	233	208	161	136	132	114
Olin	59	53	52	49	45	38	31	26	25	25	23
PPG Industries[c]	176	176	150	127	127	119	103	83	70	61	56
Rohm & Haas	125	124	109	100	92	77	67	54	49	45	43
Union Carbide[d]	191	275	265	245	240	207	166	161	156	156	143
TOTAL	$3347	$3345	$3016	$2697	$2502	$2186	$1888	$1630	$1448	$1288	$1182
ANNUAL CHANGE	0%	11%	12%	8%	14%	16%	16%	13%	13%	9%	9%

a Planned. b Excludes petroleum and coal segments. c Historical figures net of taxes and depreciation; 1986 estimated. d Company is divesting a substantial share of assets this year; restated on a continuing operations basis, 1985 R&D spending total was $207 million. Sources: Company data and estimates

Chemical firms' funding of energy R&D is up slightly . . .

. . . but outlays on pollution control R&D rebound



a Excludes federal funds. b C&EN estimates. Source: National Science Foundation

BASIC RESEARCH IN INDUSTRY: More than a fourth done by chemical firms

$ Millions	1984	1983	1981	1979	1977	1976	1975	1974
Chemicals and allied products	$ 677	$ 650	$ 569	$ 366	$337	$332	$298	$294
Industrial chemicals	375	370	360	190	183	168	155	130
Drugs	302	280	185	150	130	128	113	118
Other chemicals			23	26	25	36	31	46
Other industries	1901	1521	1045	792	574	505	432	415
TOTAL	$2578	$2171	$1614	$1158	$911	$837	$730	$709

Note: No data for 1978, 1980, and 1982. **Sources:** National Science Foundation and C&EN estimates based on NSF data

APPLIED RESEARCH IN INDUSTRY: Gets about 40% of chemical industry's R&D

$ Millions	1984	1983	1981	1979	1977	1976	1975	1974
Chemicals and allied products	$ 3,265	$ 2,702	$ 2,391	$1726	$1347	$1219	$1102	$ 965
Industrial chemicals	1,532	1,486	1,250	853	695	593	537	565
Drugs	1,733	1,216	890	684	479	470	426	299
Other chemicals			251	189	173	156	138	101
Other industries	12,004	10,803	8,321	5499	4289	3964	3477	3292
TOTAL	$15,269	$13,505	$10,712	$7225	$5636	$5183	$4578	$4257

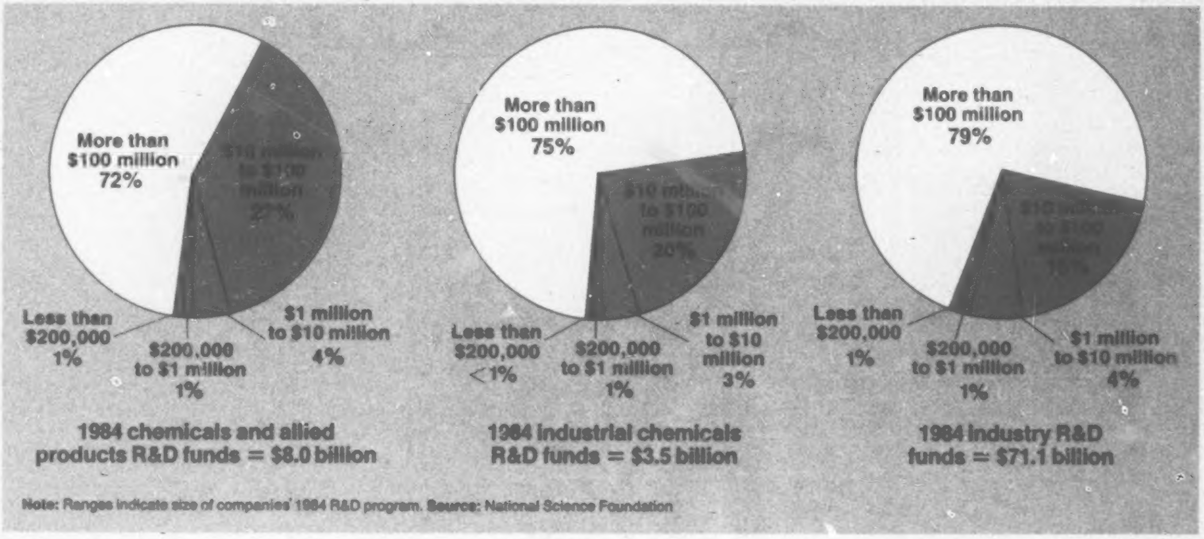
Note: No data for 1978, 1980, and 1982. **Sources:** National Science Foundation and C&EN estimates based on NSF data

DEVELOPMENT IN INDUSTRY: Chemical industry accounts for nearly 8% of total

$ Millions	1984	1983	1981	1979	1977	1976	1975	1974
Chemicals and allied products	$ 4,082	$ 3,941	$ 2,665	$ 1,946	$ 1,518	$ 1,466	$ 1,330	$ 1,191
Industrial chemicals	1,641	1,555	1,191	920	790	763	700	604
Drugs	2,441	2,386	1,000	682	508	493	444	390
Other chemicals			475	344	219	209	184	197
Other industries	49,738	43,786	36,819	27,897	21,760	19,511	17,550	16,730
TOTAL	$53,820	$47,727	$39,484	$29,843	$23,278	$20,977	$18,879	$17,921

Note: No data for 1978, 1980, and 1982. **Sources:** National Science Foundation and C&EN estimates based on NSF data

More than 70% of R&D is done by firms that spend some $100 million on it annually



1984 chemicals and allied products R&D funds = $8.0 billion

1984 industrial chemicals R&D funds = $3.5 billion

1984 industry R&D funds = $71.1 billion

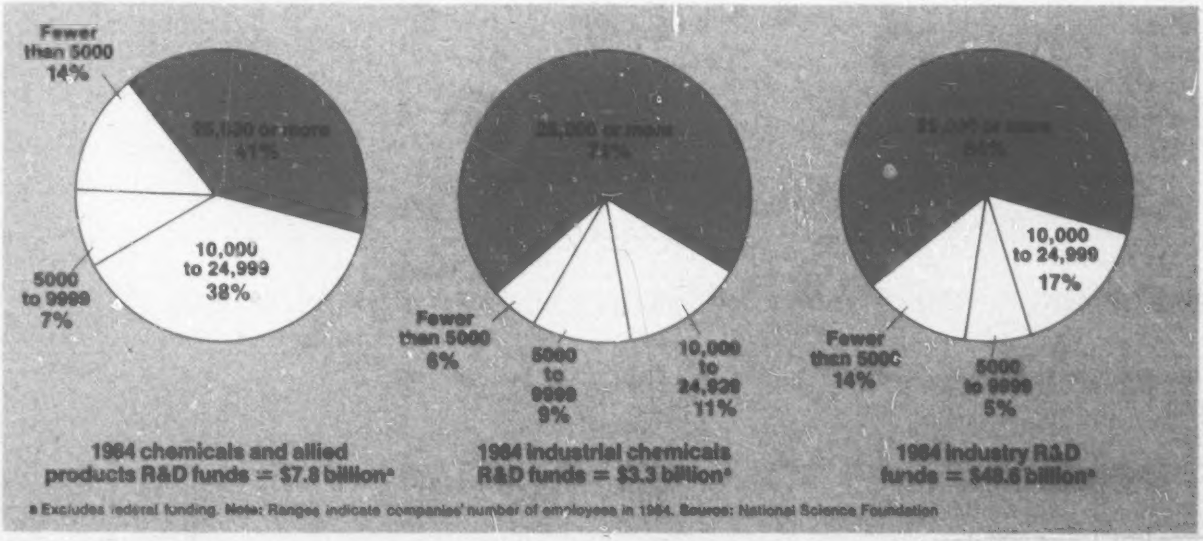
Note: Ranges indicate size of companies' 1984 R&D program. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Down in industrial chemicals but up for drugs

Thousands[a]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	**66.9**	**67.1**	**66.0**	**61.6**	**54.7**	**51.4**	**50.0**	**48.3**	**46.4**	**44.4**	**45.2**
Industrial chemicals	25.1	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6	20.1	21.1
Drugs	30.9	30.1	28.2	25.6	23.3	21.6	20.9	19.5	17.8	16.6	15.6
Other chemicals	10.9	10.3	10.6	10.1	9.8	8.9	7.9	7.5	8.0	7.8	8.5
Other industries	**503.4**	**477.4**	**456.1**	**448.2**	**433.1**	**399.2**	**373.9**	**356.1**	**336.4**	**320.0**	**318.1**
TOTAL	**570.3**	**544.5**	**522.1**	**509.8**	**487.8**	**450.6**	**423.9**	**404.4**	**382.8**	**364.4**	**363.3**

[a] Full-time equivalent. **Note:** Data as of January of each year. **Source:** National Science Foundation

Firms with more than 25,000 employees do major share of R&D



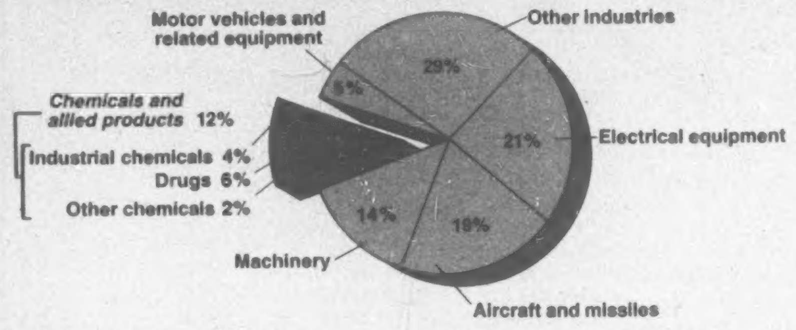
1984 chemicals and allied products R&D funds = $7.8 billion[a]

1984 industrial chemicals R&D funds = $3.3 billion[a]

1984 industry R&D funds = $48.6 billion[a]

[a] Excludes federal funding. **Note:** Ranges indicate companies' number of employees in 1984. **Source:** National Science Foundation

Chemical industry employs 12% of scientists and engineers doing industrial research



1985 total industrial R&D scientists and engineers[a] = 570,300

a Full-time equivalent, as of January 1985. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: Down slightly for chemical firms

	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
Chemicals and allied products	53	54	51	44	42	42	43	42	40	41	40	39	39
Industrial chemicals	42	45	44	37	36	36	38	38	36	38	37	36	34
Drugs	88	82	74	66	60	62	65	62	64	59	57	57	60
Other chemicals	36	36	36	33	30	27	27	29	28	29	30	29	31
All industry	36	35	33	29	27	27	27	27	27	26	25	24	24

Source: National Science Foundation

COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: Nearly twice what it was in mid-1970s

$ Thousands	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Chemicals and allied products	$119.8	$109.6	$104.4	$ 96.6	$ 87.4	$79.6	$72.8	$67.6	$66.5	$60.9	$56.3
Industrial chemicals	137.0	126.6	124.3	118.0	103.4	92.8	84.2	79.6	74.7	67.5	63.5
Drugs	a	a	a	a	79.2	71.4	64.8	59.9	63.4	60.9	54.3
Other chemicals	a	a	a	a	66.5	66.5	61.6	53.8	50.8	43.2	45.3
All industry	$127.6	$118.9	$112.4	$103.9	$ 94.9	$87.4	$80.4	$75.8	$72.2	$66.5	$63.3

a Not separately available but included in chemicals and allied products. **Source:** National Science Foundation

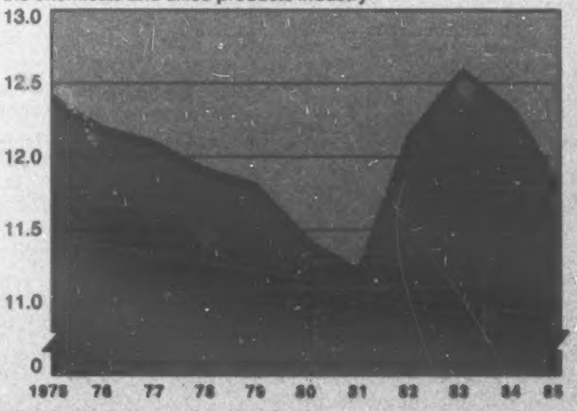
CHEMISTS IN INDUSTRY: More Ph.D.s work for chemical industry than any other industry

	% of industrial chemists			
Industry	**All chemists**	**B.S.**	**M.S.**	**Ph.D.**
Pharmaceuticals[a]	18%	17%	19%	18%
Chemicals[b]	16	13	15	19
Agricultural chemicals	7	5	6	9
Petroleum and natural gas	6	5	5	8
Coatings	6	8	6	4
Electronics	5	6	5	5
Biochemicals and biotechnology	4	3	3	5
Food	4	5	5	3
Metals and minerals	3	4	3	2
Soaps and detergents	3	3	3	2
Rubber	2	3	3	2
Paper	2	2	1	2
Other manufacturing	17	17	17	16
Nonmanufacturing	7	10	9	5

a Includes personal-care products. b Excludes chemical fields listed separately. **Source:** 1986 ACS survey

Share of R&D scientists and engineers in chemical firms has declined since 1983

% of total industrial R&D scientists and engineers in the chemicals and allied products industry[a]



a Full-time equivalent, as of January of each year.
Source: National Science Foundation

R&D support expands more rapidly

CHARACTER OF UNIVERSITY R&D SPENDING: Two thirds of total is for basic studies

$ Millions	1985[a]	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Basic research	$6350	$5622	$5239	$4867	$4576	$4026	$3612	$3176	$2800	$2549	$2410	13%	10%
Applied research	2600	2376	2105	2006	1866	1691	1465	1213	1067	1015	851	9	12
Development	550	475	437	415	377	343	284	236	200	164	148	16	14
TOTAL	**$9500**	**$8473**	**$7781**	**$7288**	**$6819**	**$6060**	**$5361**	**$4625**	**$4067**	**$3729**	**$3409**	**12%**	**11%**

a Estimated. b Estimated, based on data from Ph.D.-granting institutions only. **Note:** Data for institutional fiscal years. **Source:** National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Industry support is still small but growing most rapidly

$ Millions	1985[a]	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Federal government	$6050	$5387	$4956	$4752	$4562	$4094	$3595	$3059	$2726	$2512	$2288	12%	10%
Industry	550	456	378	334	291	235	193	170	139	123	113	21	17
Universities	2200	2000	1864	1702	1520	1323	1200	1037	868	810	749	10	11
Other sources	700	630	583	500	446	408	373	359	314	284	259	11	10
TOTAL	**$9500**	**$8473**	**$7781**	**$7288**	**$6819**	**$6060**	**$5361**	**$4625**	**$4067**	**$3729**	**$3409**	**12%**	**11%**

a Estimated. b Estimated, based on data from Ph.D.-granting institutions only. **Note:** Data for institutional fiscal years. **Source:** National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: 4% of total funds goes to chemistry

$ Millions	1985[a]	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Physical sciences	**$1130**	**$ 994.8**	**$ 898.8**	**$ 826.1**	**$ 766.3**	**$ 677.4**	**$ 601.9**	**$ 496.4**	**$ 423.5**	**$ 379.4**	**$ 350.3**	**14%**	**12%**
Chemistry	420	370.1	335.6	309.9	285.1	244.0	206.4	183.1	159.4	140.1	120.7	13	13
Physics	540	469.7	414.3	366.5	357.2	322.2	292.0	235.1	201.7	183.1	173.5	15	12
Engineering	**1350**	**1202.6**	**1109.4**	**1029.4**	**961.0**	**864.9**	**768.4**	**601.1**	**498.5**	**431.7**	**380.9**	**12**	**13**
Chemical	105	95.9	90.6	83.8	83.2	67.6	na	na	na	na	na	9	na
Total R&D spending	**$9500**	**$8472.7**	**$7781.5**	**$7287.6**	**$6818.6**	**$6060.3**	**$5361.4**	**$4624.7**	**$4067.0**	**$3729.0**	**$3408.7**	**12%**	**11%**

a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. **Note:** Data for institutional fiscal years. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Increase last year best since 1980

$ Millions	1985[a]	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Physical sciences	**$ 880**	**$ 779.1**	**$ 698.4**	**$ 650.0**	**$ 619.0**	**$ 554.8**	**$ 490.7**	**$ 392.3**	**$ 338.8**	**$ 305.4**	**$ 265.0**	**13%**	**12%**
Chemistry	315	279.0	248.5	231.1	216.8	189.4	156.5	138.0	121.5	107.9	92.7	13	13
Physics	440	387.5	340.0	306.2	308.7	279.9	252.5	199.2	171.9	156.1	149.9	14	11
Engineering	**880**	**778.7**	**737.6**	**698.2**	**682.5**	**595.4**	**526.4**	**407.5**	**336.7**	**280.5**	**238.4**	**13**	**13**
Chemical	60	54.4	52.1	49.6	55.2	46.1	na	na	na	na	na	10	na
Total R&D spending	**$6050**	**$5386.6**	**$4956.1**	**$4752.2**	**$4561.8**	**$4096.0**	**$3595.3**	**$3058.7**	**$2726.1**	**$2511.9**	**$2288.1**	**12%**	**10%**

a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. **Note:** Data for institutional fiscal years. **Source:** National Science Foundation

TOP 12 UNIVERSITIES IN R&D SPENDING: Johns Hopkins, MIT spend most on physical science

$ Millions, fiscal 1984	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math and computer sciences	Other sciences[b]	Total
Johns Hopkins U	$56.9	$ 4.0	$108.2	$30.1	$ 81.9	$61.1	$12.7	$350.9
Massachusetts Inst. of Technology	63.6	11.7	90.3	12.0	31.1	12.5	12.6	222.1
U of Wisconsin, Madison	19.3	6.1	19.7	14.5	103.6	7.4	19.7	184.2
Stanford U	27.5	6.8	50.3	3.0	75.4	13.4	5.0	174.7
Cornell U	27.1	6.7	27.3	4.5	97.5	3.5	9.5	169.5
U of Minnesota	9.0	4.1	15.9	3.4	120.6	2.8	6.5	158.2
U of Michigan	10.9	2.8	19.9	8.5	74.9	3.5	38.3	156.0
U of Washington	8.2	2.3	10.1	14.2	91.8	3.0	19.7	148.9
U of California, San Diego	18.9	4.4	1.4	64.4	49.7	2.8	3.7	141.0
U of California, Berkeley	25.4	7.9	29.2	2.1	56.5	3.3	17.4	133.8
U of California, Los Angeles	14.7	7.2	16.4	8.1	80.8	1.2	10.9	132.1
Columbia U, main division	12.6	4.7	7.6	23.0	71.8	2.8	6.6	124.3

a Included in physical sciences. b Includes social sciences, psychology, and other sciences not listed separately. Source: National Science Foundation

TOP 12 UNIVERSITIES R&D CENTERS: Physical sciences get most funds

$ Millions, fiscal 1984	Physical sciences	Engineering	Environmental sciences	Math and computer sciences	Total[a]
Lawrence Livermore National Lab	$203.3	$378.0	$23.8	$82.5	$707.2
Los Alamos National Lab	301.0	201.3	14.9	53.9	619.3
Jet Propulsion Lab	86.3	209.5	46.0	179.8	521.5
Lincoln Lab	45.7	169.3	0	25.3[b]	240.5
Argonne National Lab	61.3[b]	105.5[b]	27.1[b]	2.9[b]	209.1[b]
Brookhaven National Lab	128.2	28.2	9.4	0.6	191.6
Fermi National Accelerator Lab	143.7	0	0	0	143.7
Plasma Physics Lab	138.8	0	0	0	138.8
Lawrence Berkeley Lab	78.7[b]	12.5[b]	13.4[b]	4.2[b]	132.7[b]
Stanford Linear Accelerator Center	74.5	0	0	0	74.5
National Center for Atmospheric Research	4.2	0	38.4[b]	0	42.7[b]
National Optical Astronomy Observatory	24.9	0	0	0	24.9

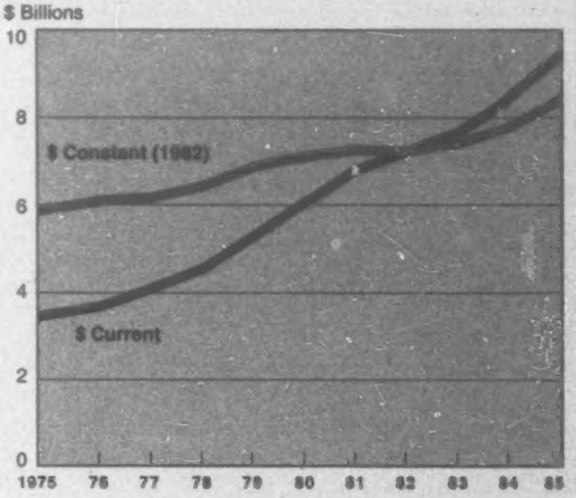
a Includes life sciences and other sciences not listed separately. b Estimated. Note: Data for university-administered federally funded R&D centers. Source: National Science Foundation

ACADEMIC SCIENTISTS AND ENGINEERS: Chemists account for 5% of total

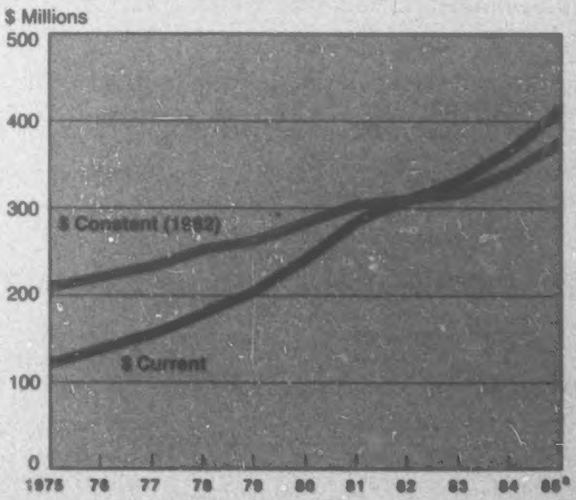
Thousands of scientists and engineers[a]	1985	1984	1983	1982	1981	1980	1978
TOTAL							
Physical scientists	36.5	35.9	34.8	34.5	34.1	33.6	32.8
Chemists	19.1	18.8	18.3	18.1	18.1	17.6	17.7
Physicists	14.1	13.9	13.6	13.3	12.9	13.0	12.8
Engineers	39.9	38.7	37.7	36.4	34.9	33.7	31.0
Chemical	2.6	2.5	2.4	2.3	2.3	2.4	2.0
Other scientists	304.0	295.9	286.4	278.2	265.6	256.9	243.9
TOTAL	380.4	370.5	358.9	349.1	334.6	324.2	307.8
FULL TIME ONLY							
Physical scientists	29.5	29.3	28.5	28.6	28.2	28.0	27.9
Chemists	15.1	15.1	14.8	14.7	14.8	14.3	14.7
Physicists	11.9	11.8	11.4	11.4	11.0	11.3	11.3
Engineers	30.1	29.3	28.8	28.0	27.0	26.5	24.7
Chemical	2.2	2.0	2.0	1.9	1.9	1.9	1.7
Other scientists	228.0	222.0	216.8	212.0	204.5	200.5	189.6
TOTAL	287.6	280.6	274.1	268.6	259.7	255.0	242.2

a In January. Note: Data not available for 1979. Source: National Science Foundation

Total spending for academic R&D, in real terms, gets a boost as inflation slows . . .



. . . and funding for academic chemistry also scores best recent real growth



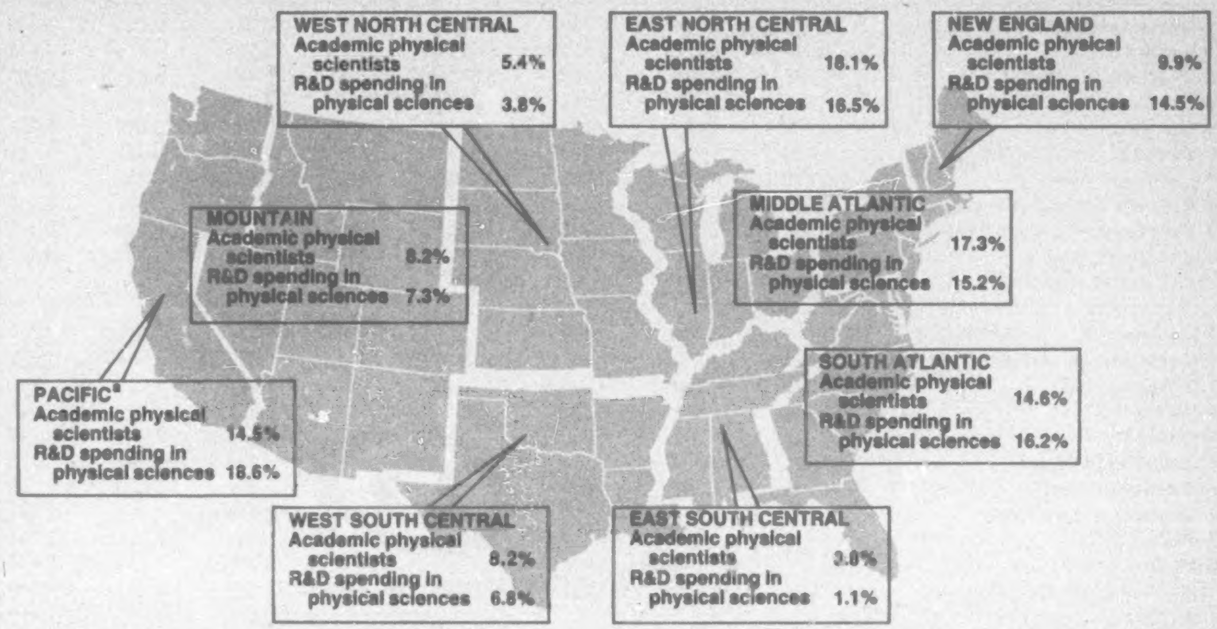
a C&EN estimates. Note: Data for institutional fiscal years. Source: National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: 20% of total goes to top 10 institutions

$ Thousands	Total spending				Federally financed spending			
	1984	1983	1982	1981	1984	1983	1982	1981
1 Massachusetts Inst. of Technology	$ 11,741	$ 8,914	$ 9,792	$ 8,222	$ 11,055	$ 8,374	$ 9,096	$ 7,572
2 Harvard U	8,327[a]	6,898[a]	5,512[a]	6,123[a]	6,307	5,224	4,174	4,637
3 U of California, Berkeley	7,850	7,945	6,283	6,553	7,263	7,467	5,691	6,008
4 U of California, Los Angeles	7,219	5,496	5,187	4,420	6,389	5,047	4,978	4,127
5 Stanford U	6,809	6,589	6,634	5,564	6,120	5,068	5,893	5,337
6 Cornell U	6,710	5,717[a]	6,239[a]	4,618	5,775	4,766	5,437	4,062
7 U of Texas, Austin	6,639	5,938	4,843	4,779	3,873	3,527	2,781	3,017
8 California Inst. of Technology	6,446	6,994	6,136	6,901	5,810	6,554	5,809	6,196[a]
9 U of Maryland, College Park	6,324	6,333[a]	4,718[a]	3,109	2,862	2,834	3,088	2,418
10 U of Illinois, Urbana	6,284	5,886	6,422	5,239	5,005	4,668	4,763	3,847
Total, first 10 institutions	74,349	66,710	61,766	55,528	60,459	54,429	51,690	47,221
11 U of Massachusetts, Amherst	6,137	5,162	4,364	3,230	3,784	3,336	2,773	2,067
12 U of Wisconsin, Madison	6,076	5,310	4,567	4,122	4,391	3,693	3,404	3,134
13 U of Chicago	5,735	4,798[a]	4,396[a]	4,139[a]	5,116	3,998	3,716	3,719
14 Indiana U	5,642	5,551	5,341	3,637	4,694	4,642	4,237	3,042
15 Purdue U	5,443	4,542	4,459	4,600	4,452	3,966	3,946	3,715
16 Pennsylvania State U	5,124	4,729	3,564	3,413	4,564	4,236	3,222	2,773
17 U of Notre Dame	4,760	4,022	4,020	3,855	4,416	3,667	3,866	3,738
18 Columbia U, main division	4,662	4,281	4,700	3,564	4,639	4,279	4,365	3,471
19 Texas A&M U	4,610	4,963	4,521	4,069	2,735	3,327	2,823	2,793
20 Northwestern U	4,557	3,413	3,026	2,995	3,471	3,012	2,711	2,813
Total, first 20 institutions	127,095	113,481	104,724	93,152	102,721	92,785	86,753	78,486
21 U of Pennsylvania	4,375	4,982	3,068	3,386	3,921	4,037	2,745	3,073
22 U of California, San Diego	4,355	3,910	3,894	4,430	3,780	3,490	3,506	3,933
23 U of Oregon, main campus	4,255	3,351	2,971	1,389	3,524	2,686	2,530	1,235
24 U of Connecticut	4,135	2,720	2,049	1,748	2,753	1,445	1,113	1,022
25 Yale U	4,134	3,341	2,875	2,781	3,528	3,008	2,599	2,609[a]
26 U of Colorado	4,134	3,302	3,492	4,047	3,358	2,695	2,755	3,146
27 Ohio State U	4,104	3,616[a]	2,907	3,227	2,904	2,786[a]	2,355	2,679
28 U of Minnesota	4,067	4,047	4,297	4,260	3,346	3,345	3,377	3,494
29 Johns Hopkins U	4,030	4,592[a]	4,721	4,066	3,783	3,604[a]	3,800	3,881
30 U of Florida	4,024	2,347	2,248	2,302	2,042	1,325	1,341	1,156
Total, first 30 institutions	168,708	149,689	137,246	124,788	135,660	121,206	112,874	104,714
31 U of Pittsburgh	3,965	3,267	2,714	2,039	3,343	2,833	2,188	1,581
32 U of Rochester	3,858	3,167	3,123	2,966	3,490	2,800	2,774	2,553
33 Georgia Inst. of Technology	3,846	3,401	3,327	3,660	2,227	2,032	1,800	2,030
34 U of Utah	3,830	3,638	3,364	3,076	3,380	3,085	2,858	2,720
35 Howard U	3,672	2,336	982	1,406	3,300	2,069	867	1,248
36 Princeton U	3,670	3,509	3,062	2,513	2,892	2,642	2,485	2,142
37 U of South Carolina	3,423	2,721	2,483	1,087[b]	2,533	2,221	1,865	902[b]
38 Lehigh U	3,361	3,664	2,584	1,680	1,372	1,498	1,189	1,063
39 State U of New York, Stony Brook	3,084	2,607	2,783	2,691	2,156	1,809	1,901	2,080
40 Wayne State U	3,071	2,645	2,656	2,261	2,104	1,813	1,799	1,636
Total, first 40 institutions	204,488	180,644	164,324	148,167	162,457	144,006	132,600	[illegible]
41 U of North Carolina, Chapel Hill	2,945	2,397	2,240	2,016	2,699	2,381	2,218	1,936
42 U of Southern California	2,929	3,404	2,401	2,345	2,495	2,456	1,717	1,639
43 Arizona State U	2,875	3,062	2,323	2,153	2,014	2,124	1,996	1,958
44 Michigan State U	2,869[b]	2,714	2,493	2,178	2,044[b]	1,995	1,832	1,541
45 U of Michigan	2,786	2,244	2,064	2,016	2,356	1,853	1,547	1,591
46 Case Western Reserve U	2,759	2,232	2,185	2,139	1,904	1,443	1,487	1,732
47 Florida State U	2,740	2,500	2,959	3,012	1,140	1,115	1,124	1,463
48 Colorado State U	2,688	2,478	2,479	2,385	2,426	2,055	2,230	2,079
49 U of Oklahoma	2,676	2,890	2,306	1,399	1,150	1,453	1,067	674
50 U of Nebraska, Lincoln	2,549	3,431[a]	3,217	2,175	1,920	1,995[a]	1,995	1,757
Total, first 50 institutions	$232,304	$207,996	$188,991	$169,985	$182,605	$162,878	$149,813	$139,039
NATIONAL TOTAL	$370,123	$335,827	$309,889	$285,061	$279,035	$248,470	$231,108	$216,783

a Estimated. b Imputed. Note: Data for institutional fiscal years. Source: National Science Foundation

Schools east of the Mississippi account for close to two thirds of academic physical scientists and academic R&D spending in the physical sciences


WEST NORTH CENTRAL
Academic physical scientists 5.4%
R&D spending in physical sciences 3.8%
EAST NORTH CENTRAL
Academic physical scientists 18.1%
R&D spending in physical sciences 16.5%
NEW ENGLAND
Academic physical scientists 9.9%
R&D spending in physical sciences 14.5%
MOUNTAIN
Academic physical scientists 8.2%
R&D spending in physical sciences 7.3%
MIDDLE ATLANTIC
Academic physical scientists 17.3%
R&D spending in physical sciences 15.2%
PACIFIC[a]
Academic physical scientists 14.5%
R&D spending in physical sciences 18.6%
SOUTH ATLANTIC
Academic physical scientists 14.6%
R&D spending in physical sciences 16.2%
WEST SOUTH CENTRAL
Academic physical scientists 8.2%
R&D spending in physical sciences 6.8%
EAST SOUTH CENTRAL
Academic physical scientists 3.8%
R&D spending in physical sciences 1.1%

Key to map: Using the Middle Atlantic states as an example, 17.3% of all physical scientists employed at Ph.D.-granting universities and colleges in the U.S. are located in this geographical area and 15.2% of all R&D expenditures in the physical sciences by all Ph.D.-granting universities and colleges are made in this area. a Includes Alaska, Hawaii, and outlying areas. **Note:** Data are based on 20,699 physical scientists employed at Ph.D.-granting universities and colleges in the U.S. as of January 1985 and R&D expenditures of $972.9 million in the physical sciences during the 1984 fiscal year of all universities and colleges. **Source:** National Science Foundation

CHEMICAL DEGREES: Chem engineering graduate numbers continue to increase

Academic year	Degrees awarded in chemistry[a]			Degrees awarded in chemical engineering		
	Bachelors	Masters	Ph.D.s	Bachelors	Masters	Ph.D.s
1965–66	9,735	1839	1571	2848	994	354
1966–67	9,872	1831	1744	2869	949	305
1967–68	10,847	2014	1757	3211	1156	367
1968–69	11,807	2070	1941	3557	1136	409
1969–70	11,617	2146	2208	3720	1045	438
1970–71	11,183	2284	2160	3615	1100	406
1971–72	10,721	2259	1971	3663	1154	394
1972–73	10,226	2230	1882	3636	1051	397
1973–74	10,525	2138	1828	3454	1045	400
1974–75	10,649	2006	1824	3142	990	346
1975–76	11,107	1796	1623	3203	1031	308
1976–77	11,322	1775	1571	3581	1086	291
1977–78	11,474	1892	1525	4615	1237	259
1978–79	11,643	1765	1518	5655	1149	304
1979–80	11,446	1733	1551	6383	1271	284
1980–81	11,347	1654	1622	6527	1267	300
1981–82	11,062	1751	1722	6740	1285	311
1982–83	10,746	1604	1746	7145	1304	319
1983–84	10,704	1667	1774	7475	1514	330

a Data do not include biochemistry and geochemistry. **Source:** Department of Education's National Center for Education Statistics

GRADUATE SCIENCE STUDENTS: 6% are majoring in chemistry or biochemistry

Thousands	1984	1983	1982	1981	1980	1979	1978
TOTAL							
Physical sciences	28.4	27.7	26.5	25.8	25.4	24.9	24.7
Chemistry	16.6	16.5	15.8	15.2	15.1	14.9	14.8
Physics	11.0	10.5	10.0	9.9	9.6	9.3	9.2
Engineering	88.2	86.0	78.2	74.4	70.1	67.2	64.3
Chemical	7.2	7.4	6.9	6.3	5.9	5.4	5.2
Metallurgical and materials	3.6	3.3	3.0	3.0	2.8	2.7	2.5
Petroleum	0.7	0.7	0.6	0.5	0.5	0.4	0.4
Life sciences	92.6	91.2	90.7	90.9	90.7	87.5	85.9
Biochemistry	4.5	4.2	4.1	4.0	4.0	3.9	4.0
Other sciences[a]	154.3	153.3	151.4	148.9	147.5	141.0	134.9
TOTAL	363.5	358.2	346.8	340.0	333.7	320.6	309.8
FULL TIME ONLY							
Physical sciences	25.1	24.5	23.3	22.6	22.3	21.8	21.5
Chemistry	14.6	14.5	13.7	13.2	13.1	12.8	12.7
Physics	9.8	9.4	8.9	8.8	8.5	8.3	8.2
Engineering	54.8	53.5	48.7	44.8	41.9	39.3	37.1
Chemical	5.7	5.8	5.5	4.9	4.4	4.2	3.9
Metallurgical and materials	2.9	2.7	2.5	2.4	2.2	2.1	2.0
Petroleum	0.6	0.6	0.5	0.4	0.4	0.3	0.3
Life sciences	66.2	65.2	65.7	67.2	67.7	66.5	65.2
Biochemistry	4.3	4.0	3.8	3.7	3.7	3.6	3.7
Other sciences[a]	100.7	100.4	99.2	99.6	98.6	95.8	92.8
TOTAL	246.8	243.6	236.9	234.2	230.5	223.4	216.6

a Includes environmental, mathematical, computer, and social sciences and psychology. **Note:** Data for Ph.D.-granting institutions only. **Source:** National Science Foundation

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NEWS

NASA steps up efforts
to redesign space shuttle
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Titanium Dioxide

Producers expect best year ever
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CHEMICAL & ENGINEERING
NEWS

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AUGUST 4, 1986

News of the Week

- **House/Senate conferees resolve nontax issues in compromise Superfund bill.** **Page 4**
- **Jury finds W. R. Grace & Co. responsible for contributing to contamination of municipal wells in Woburn, Mass.** **Page 5**
- **No harmful effects resulted when boxcars containing insecticide and chemicals were blown off a trestle during a windstorm near Des Moines, Iowa.** **Page 5**
- **OSHA proposes standards for lab workers' exposure to toxic substances.** **Page 6**
- **Nobelist Fritz A. Lipmann, discoverer of coenzyme A, is dead at age 87.** **Page 6**

Cover: Du Pont's DeLisle, Miss., plant is largest single-line titanium dioxide facility in the world

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Business

Titanium dioxide producers expect best year ever as prices hold firm and production and consumption rise. **Page 15**

Government

Study of safety at chemical plants by the Occupational Safety & Health Administration finds deficiencies in present inspection system. **Page 18**

Technology

Liquid-phase process for methanol synthesis is being developed by researchers at Brookhaven National Laboratory. **Page 21**

Methods to use microwave ovens to dissolve samples for elemental trace analysis are being developed. **Page 22**

Books

"The Ageless Gergel" relates episodes from the author's life as an entrepreneur running a small chemical business. **Page 23**

ACS News

ACS Council will decide on planning document and four petitions when it convenes at society's national meeting in Anaheim. **Page 25**

News Focus

NASA works to redesign space shuttle following recommendations of Presidential commission, aiming for an early 1988 launch. **Page 7**

Titanium Dioxide Producers Expect Best Year Ever

Prices for largest-volume white pigment hold firm as production and consumption rise and capacity expansion programs continue

Bruce F. Greek, C&EN Houston

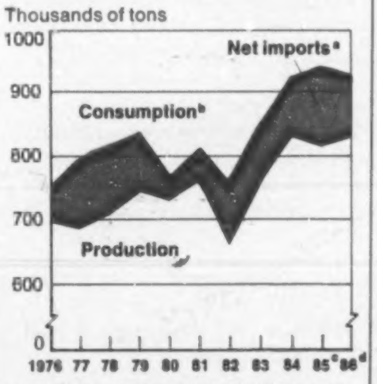
Titanium dioxide consumption in the U.S. this year will rise to a new high, giving producers their best year ever. The growth in demand will push up production as well as increase the net of imports over exports. Demand, production, and imports all have increased substantially, but this growth will slow later this year. Supplies are tight, with selling prices very close to list prices, which recently were raised.

Production, tempered somewhat by maintenance requirements, is expected to remain high during the rest of the year. Imports may decline as consumption slows because of its seasonal pattern. Inventories of titanium dioxide have been low, but they likely will be rebuilt slightly this fall.

According to preliminary estimates, U.S. production of titanium dioxide this year is forecast to exceed 830,000 tons, up 2% from 1985. Some industry sources question the validity of the 1985 government production figure, however, saying the estimate is low because it is more than 20,000 tons less than the 1984 production estimate for a year when demand was as strong or stronger than in 1984. Producers say that last year they were responding to increased demands from most titanium dioxide uses and were drawing down inventories to meet those demands. The net of imports over exports in 1985 was up 7000 tons from the year before to 94,000 tons, which was only a minor addition to supplies for the year. Thus, producers explain, for the government to report decreased production calls the figures into question.

If production estimates for 1985 are revised, the total may be very close to the 1984 volume or higher, according to sources. Should the 1985 production estimate end up being 835,000 to 840,000 tons, then production plus the net of imports over exports and inventory drawdown would about equal consumption, which is estimated to be in the range of 930,000 to 940,000 tons.

Producers this year could add another 10,000 to 15,000 tons to supply. If the net of imports over exports increases about 5000 to 10,000 tons, consumption theoretically might rise 15,000 to 25,000 tons, to more than 950,000 tons. Such an increase in consumption likely will not occur, however, since use is forecast to grow only 1 to 1.5% in 1986. Consumption more likely will increase 8000 to 10,000 tons in 1986, allowing the additional production and imports to augment the low inventories.



TiO_2 consumption varied erratically in past decade

a Imports minus exports. b Includes shifts in inventories. c Preliminary. d Estimates. **Sources:** Department of Commerce, Bureau of Mines, C&EN estimates

Producers are again operating their plants at very high levels. For 1986 production to total the lowest estimate of 830,000 tons, the capacity of 890,000 tons that existed at the beginning of the year would have to be operated at 93% of the nameplate total. Expansions and debottlenecking programs, however, are adding to capacity. Early this year, Kerr-McGee completed an 8000 ton-per-year addition to its capacity, which could increase production about 6000 tons during the year. Debottlenecking at other facilities could add at least as much—possibly 10,000 tons—to the nameplate capacity total. Much of it will come from Du Pont's expansion program, which is designed to add a total of 50,000 tons of capacity to its four U.S. titanium dioxide plants by the end of 1988. Should the additions bring the average nameplate capacity total for the year up to 900,000 tons and production reach 850,000 tons, the average plant operating rate would be even higher—more than 94%.

If plants are operated at that kind of rate for long periods, producers likely will be able to keep their selling prices up. Last fall, prices increased 4 cents a lb, to 74 cents, for the anatase form of titanium dioxide, and 78 cents a lb for the rutile form.

Other than cost savings, which result from technological improvements at plants, the major area of cost reduction for producers is transportation savings that result from lower oil prices. Those savings, however, are offset by the additional costs of improved water pollution control and of waste disposal from manufacturing. Most of the wastes are iron chlorides and iron sulfate, which is a great problem for plants using the sulfate process.

Even though prices for titanium dioxide are now firm and higher, returns aren't enough to justify building a plant. A new plant in the U.S. could cost $2000 per ton of annual capacity, with present world-scale plants having a capacity of at least 30,000 tons per year. If a plant with such a capacity operated at 90% of nameplate, a payout in four years would require a 28 cent-per-lb capital-cost burden. As a result, it is not economically feasible to build new plants, so extensive debottlenecking programs are expected to continue well into the 1990s.

Even so, supplies of titanium dioxide will remain tight. Exports of the pigment could decline about three years from now when new capacity in various parts of the world comes on stream to fill demand in areas such as the Far East. However, U.S. imports also could decline as demand picks up in Europe (which is the source of much of the imported material), and as capacity there declines because of pressure to reduce pollution from plant effluents. The yet unbuilt foreign plants could be a future source of imports to the U.S. in the 1990s.

For the past two years, producers have managed to stay ahead of demand increases through their debottlenecking programs and increased operating rates. Demand has risen steadily, but at a relatively low rate for the chemical industry—1 to 2% annually. The major uses of titanium dioxide—coatings, paper, and plastics—have accounted for nearly all of the growth in consumption. That pattern likely will continue.

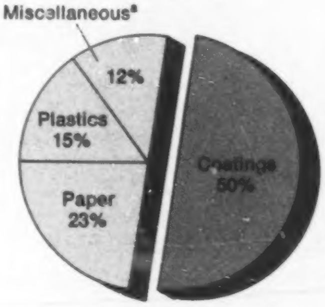
Half of U.S. consumption of titanium dioxide is used for coatings. Roughly two thirds of that is employed in exterior and interior paints. On average, more than 1 lb of titanium dioxide is used in every gallon of finished paint.

The architectural paint demand (to distinguish from paint for autos and other products) for titanium dioxide has been especially strong in 1986, because lower mortgage rates have encouraged new house construction, and that has stepped up sales of older houses. That usually involves painting all or a major part of the house before or soon after the sale.

About 20 to 25% of total coatings are used on products such as cars, machinery, appliances, containers, and many other consumer items. Demand for most of those products has been increasing modestly this year. The remainder of the nonarchitectural coatings go for repainting or refinishing in such varied uses as road stripping and auto repainting.

For these various uses for coatings, the net gain in consumption of titanium dioxide this year will be more than 1%, or about 5000 tons. That will be half of the expected growth in consumption for the year.

Coatings dominate uses of titanium dioxide



Total 1986 consumption = 920,000 tons

[a] Includes ceramics, elastomers, fabrics and textiles, floor coverings, inks, and others.
Source: C&EN estimates

Paper takes nearly another quarter of titanium dioxide consumption. The use in paper also will increase only modestly, because of variations in demand for paper and paperboard. Demand for coated papers used in higher-quality printing will be down, whereas demand for uncoated paper and paperboard containing titanium dioxide added during manufacture will be up. The latter increase results from greater demand for data processing printout paper and for packaging.

Among the large uses, plastics have been the fastest-growing market, rising about 3% this year. Some part of the manufacture of all major thermoplastics requires titanium dioxide. Roughly a third of the titanium dioxide consumed in plastics goes into polyvinyl chloride pipe, fittings, siding, and various profiles. Another third is used for pigment polyolefins, and the rest goes into other plastics, including small-volume thermoplastics and thermosets.

The remainder of titanium dioxide is consumed in myriad small uses. The largest are ceramics, elastomers, and ink. None of the miscellaneous uses are growing very much. Many are declining in their share of consumption because their growth is even lower than that of coatings or paper. □

Titanium dioxide pigment at a glance

Description: Produced in larger quantities than any other white pigment, TiO_2 has best hiding power of any white pigments. Commercial production is concentrated in two crystalline forms, anatase and rutile grades. Rutile form has a higher density, refractive index, hiding power, and slightly higher cost. Used to provide opacity in coatings, paper, plastics, and many smaller uses

Production: 815,000 tons (both forms) in 1985; 830,000 tons estimated for 1986

Imports: 196,000 tons in 1985; 200,000 tons estimated for 1986

Exports: 102,000 tons in 1985; 100,000 tons estimated for 1986

Manufacturing processes: Involve ore beneficiation of ilmenite, preparation of TiO_2 slag by electrolytic smelting, beneficiation of natural rutile, and preparation of synthetic rutile by reduction and leaching. Ores and slag then reacted with sulfuric acid and iron (sulfate process) or chlorine and oxygen (chloride process) to produce pigment grades of TiO_2

Capacity: About 900,000 tons at beginning of 1986

Producers: Du Pont, Kemira (Finnish-owned), Kerr-McGee, SCM

Prices: 74 cents per lb for anatase; 78 cents per lb for rutile (at midyear)

OSHA Issues Interim Report on Special Emphasis Program

In-depth study of safety at chemical plants identifies deficiencies in routine inspections that will effect changes in agency's approach

David J. Hanson, C&EN Washington

Frightened by the possibility of an industrial chemical accident on the magnitude of the one in Bhopal, India, the Occupational Safety & Health Administration last year began what it calls a Chemical Industry Special Emphasis Program to try to minimize the chances of such an occurrence. The initial phase of that program, in effect since January, is scheduled to end in November. OSHA has just issued an interim report on its progress.

OSHA says its findings are still highly preliminary, and it doesn't make any comment on the actual inspections themselves or how individual chemical plants fared in the process. But the special emphasis of this program is identifying enough deficiencies in the present system that it will change permanently the way OSHA inspects chemical plants.

After the Bhopal accident in December 1984, OSHA was under extreme pressure from Congress to assure the public that such a catastrophe could not happen in the U.S. OSHA inspected all the plants where methyl isocyanate—the chemical involved in the Bhopal deaths—was being manufactured. Although some violations of safety and health standards were found, there did not appear to be any imminent danger. Then, on Aug. 11, 1985, Union Carbide's plant in Institute, W.Va., experienced a leak of dichloromethane and aldicarb oxime that sent more than 100 nearby residents to hospitals with minor complaints. After the initial investigation of that incident, OSHA went into the Institute plant and did a wall-to-wall inspection of all 18 units, concluding there were some gross oversights in the way the company was handling hazardous material. Eventually the agency fined Carbide $1.4 million (C&EN, April 7, page 4). Carbide has appealed the fine.

Soon thereafter, acting assistant secretary of Labor Patrick R. Tyson announced the special emphasis program. OSHA had become aware, after the inspections for MIC, that its enforcement program needed to cover more than the physical conditions of the plant equipment—the company's management policies, its protective systems, and safe work practices also needed to be scrutinized. "Inspections conducted under the new special emphasis program will pay particular attention to safety processes in order to assess the adequacy of those processes in preventing and containing leaks and spills," Tyson told the House Subcommittee on Health & Safety last October. "The focus will be on preventing future hazards as well as discovery of existing ones."

In the current pilot-scale project OSHA is trying to inspect units producing hazardous materials at about 80 chemical plants scattered throughout four OSHA regions. At this time, OSHA inspectors have been able to make only 32 inspections, according to John B. Miles, director of OSHA field operations. It is turning out that these inspections are taking a great deal of time. Each inspection requires a two-member team of OSHA officers—a safety inspector and an industrial hygienist—and it is taking up to eight weeks or longer to complete a job. This is much longer than a routine inspection, which is done by one officer. OSHA says that the two-member teams can do no more than eight to 10 inspections each year, meaning they are in effect skipping 120 to 150 inspections elsewhere. Miles says that this is expected to eat somewhat into the regular OSHA inspection schedule for chemical plants, but that the year's total should still be near the 1400 inspections done in the past.

The agency is having a problem deciding which plants to inspect. OSHA wanted to get to those plants producing the chemicals most hazardous to the workers or surrounding communities. Having no such list of dangerous chemicals of its own, OSHA turned to a list prepared by the European Economic Community of high-risk chemicals, also known as the International Labor Organization list. The agency chose the 120 highest ranked chemicals as its targets. Then, with help from the Environmental Protection Agency, OSHA tried to match up those chemicals with manufacturers as listed in the Toxic Substances Control Act inventory list, compiled in 1978. One difficulty encountered right away was that the TSCA list does not include pesticides, whereas the ILO list does.

Unfortunately, the plants EPA thought were manufacturing those chemicals sometimes no longer were doing so. According to the interim report, this method of targeting plants may be workable, but not very efficient. Results so far are uneven. Sometimes inspectors went to plants only to find out the targeted chemical was no longer produced there. That happened to teams sent out by OSHA's Chicago regional office eight times, for instance. The

Dallas office, however, had no misdirected inspectors. In all, the report concludes that the system was sending teams to the wrong sites about half the time. The effectiveness of the list has been improved by doing more work with local offices, comparing their records with the target chemicals list as well as state-maintained lists of chemical manufacturers.

Still, the system has allowed OSHA at least to begin detailed inspection of 32 plants, of which only 14 were complete enough at the time of the report to be included. Each team is inspecting one unit at each plant, the one used to produce the target hazardous chemical. Of the plants inspected so far, phosgene is the most common target, comprising about half the inspections listed in the interim report. By inspecting in great detail the management's "paper program" for handling those chemicals, the OSHA inspectors hope to determine if it is actually being used in practice.

The inspections are geared to pay special attention to any hazards that are not covered by specific OSHA standards. OSHA says this means inspectors will have to use industry consensus standards and recognized industry practices to make safety evaluations. In such situations, the so-called general-duty clause of the Occupational Safety & Health Act is applied (under section 5[a][1]) when making citations. The inspectors are also encouraged to note problems where there are no consensus standards or codes and make recommendations for changes to employers. The employers will have to respond in writing within 30 days. According to OSHA, the general-duty clause citations in the first set of inspections covered hazards involving materials handling, lockout of safety relief devices, protection of breathing air supply, and process design problems. Recommendations to employers have involved ventilation problems, training, emergency procedures, respirator programs, pressure vessel inspection schedules, scrubber capacity, instrumentation, and a variety of process and electrical hazards.

OSHA estimates that the inspectors spent 80% of their time reviewing on-site health and safety program materials and reviewing the diagrams and dynamics of production processes. Some companies keep better records than others, Miles says, and even though these plants may be very safe, it's taking longer just to go through that process.

As a demonstration project, the scale of the program is not so large as it could be, and some compromise had to be made between the availability of resources and size of the situation. Complete wall-to-wall inspections, which would take several teams of inspectors months to complete, were out of the question, even an inspection the size of the one done at Carbide in Institute. Inspection of a single unit can supply information for future inspections, however. If there are many problems uncovered with a hazardous chemical unit, OSHA may conclude the rest of the plant may need a closer look as well and go further. Miles says that so far the chemical industry has been very cooperative, and that a lot of positive things are being found.

Most plants inspected in special program make phosgene

Plant	Chemical traced	Daily capacity	Inspection length, hours
Chevron, Cleves, Ohio	Hydrogen sulfide	800 cu ft	432
Dow Chemical, La Porte, Tex.	Phosgene	207 tons	558
Du Pont, Linden, N.J.	Sulfur trioxide[a]	na	398
Du Pont, Niagara Falls, N.Y.	Chlorine	240 tons	172
Liquid Air, Euclid, Ohio	Acetylene	7200 cu ft	97
Mobay, Baytown, Tex.	Phosgene	604 tons	399
Olin, Lake Charles, La.	Phosgene	140 tons	526
PPG Industries, La Porte, Tex.	Phosgene	35 tons	204
Rubicon, Geismar, La.	Phosgene	280 tons	246
Scientific Gas, South Plainfield, N.J.	Hydrogen selenide	na	na
Stauffer Chemical, Edison, N.J.	Bis(chloromethyl)-ether	na	558
Twin Lakes, Lockport, N.Y.	Phosgene[b]	0	136
Two-Six, Saxonburg, Pa.	Hydrogen selenide	18 lb (batch)	206
Union Carbide, West Mifflin, Pa.	Acetylene	1000 lb	150
Van de Mark, Lockport, N.Y.	Phosgene	3 tons	274

a Originally targeted for formaldehyde. b Not yet producing phosgene, recommendations based on assessment of plans. na = not available. **Source:** OSHA

The very preliminary nature of the data so far doesn't permit OSHA to make any evaluation of the special emphasis program yet, according to Miles. "It's still too early to draw conclusions about the inspections," he says. "There are no trends yet in the citations. We aren't finding a lot of things," he adds. And the goal of 80 unit inspections may have been optimistic in view of the time it is taking for each evaluation, but OSHA is not moving from this ideal yet. The detailed inspections are viewed as valuable. "We need a presence in the chemical industry," Miles says, "if just to know what is going on." Whether the pilot program will be continued or expanded next year will have to be decided later, he continues. "Right now, I don't see expanding the program; it's just too resource-intensive."

However, the special emphasis program already has prompted OSHA to develop a closer working relationship with other agencies involved in health and safety. Much information is being shared with EPA, and the report says the two agencies plan to conduct preliminary joint inspections this year to see if some kind of practical joint inspection protocol can be developed. Greater cooperation with the Nuclear Regulatory Commission is also becoming a concern. The report mentions the release of uranium hexafluoride from a storage tank at Sequoyah Falls Corp. near Gore, Okla.; in January as an example of the kinds of hazards present in the nuclear industry. □

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Chemical earnings rise again
in second quarter
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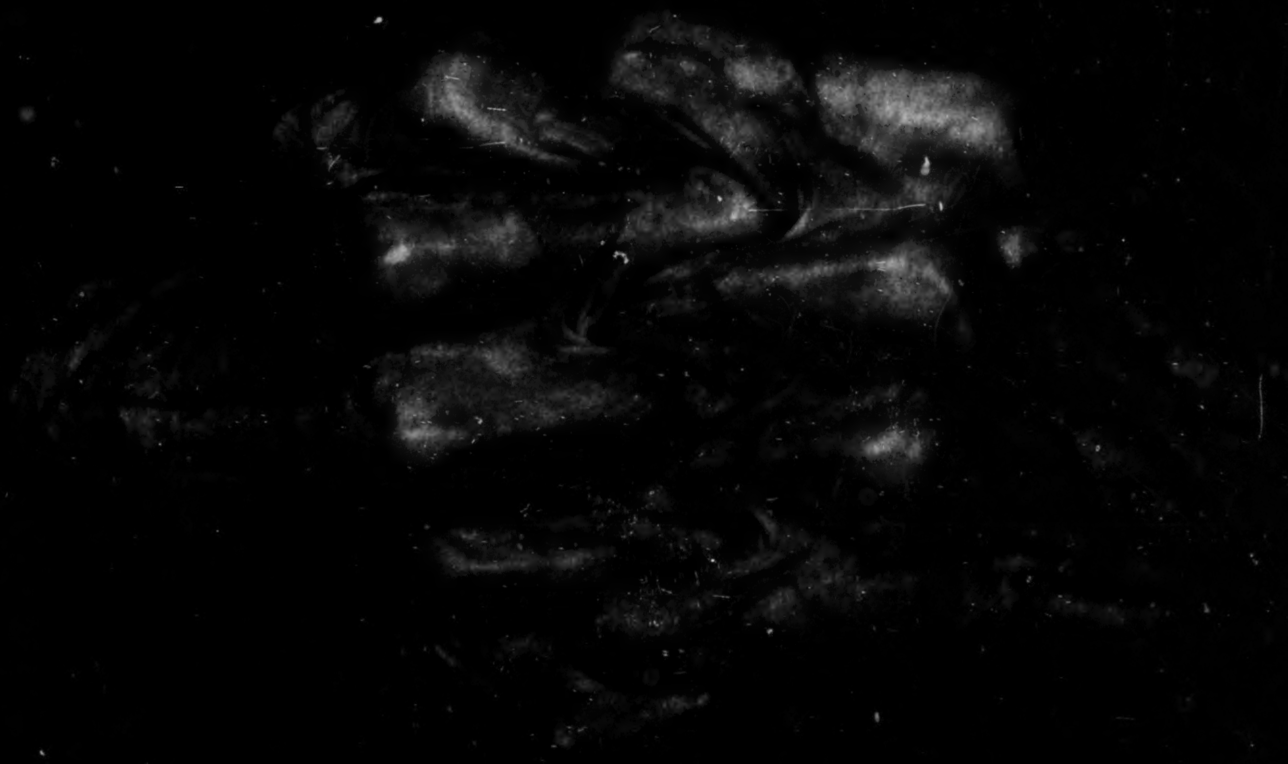
CHEMICAL & ENGINEERING NEWS



Biochemistry of Growing Old

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CHEMICAL & ENGINEERING
NEWS

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News of the Week

- **NRC advisory panel urges changes in space shuttle redesign program. Page 4**
- **Department of Energy opens Nevada test facility for hazardous fluid spills. Page 5**
- **International trade agreement for fibers and textiles extended through 1991. Page 5**
- **Congress hurries to settle issues on Superfund funding, tax reform, federal debt limit before Aug. 15 recess. Page 5**
- **With *Science Digest* and *Science 86* going to Time Inc., *Scientific American* to West German publisher, all's quiet on the science magazine front. Page 6**
- **National Cancer Institute will test antiviral nucleoside analogs for use against AIDS. Page 6**

Cover: Photo courtesy of National Institute on Aging

Business

U.S. chemical companies' earnings continued to increase in the second quarter, but oil firms' earnings were down substantially. **Page 10**

Government

President's decision to begin making binary chemical weapons this fall arouses the ire of some Congressmen. **Page 17**

Texas university professor develops theory of science policy, assessing how scientific knowledge penetrates the governance process. **Page 19**

Science

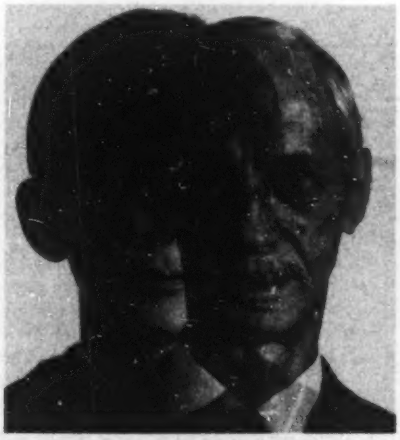
Research and application opportunities of interfaces and thin films are assessed in NAS/NAE/Institute of Medicine report. **Page 22**

Books

In "Seven Clues to the Origin of Life" author A. G. Cairns-Smith uses Sherlock Holmes-type deduction. **Page 40**

ACS News

ACS Board approves 150 new or continuing ACS/PRF grants totaling more than $4 million. **Page 43**



Special Report

The increasingly higher percentage of the elderly in the U.S. population has led to a boost in the biochemical study of aging. Research in a variety of areas has contributed pieces of the jigsaw but by no means is the puzzle complete. Page 26

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Chemical Companies' Earnings Continue To Rise in Second Quarter

William J. Storck, C&EN New York

Second-quarter earnings improved significantly for most chemical companies and diversified firms producing chemicals. But for most major oil companies, earnings were down substantially although their chemical operations fared well.

The chemical industry is continuing to reap the benefits of the major reorganization and rationalization efforts instituted in the past few years, and for many firms, these effects are accelerating. Plant shutdowns, work-force reductions, and the selling off of marginally profitable operations are having an effect on operating rates and margins, lowering breakeven points and raising profits, often in the face of declining sales dollar volumes.

Add to that some external economic factors such as increased exports as the dollar weakens abroad and subsequent increases in chemical shipments, and the stage is set for improved earnings, not only in the second quarter, but probably for the remainder of this year and into 1987 as well. The weakening of the dollar is a major force that will affect the chemical industry for some time, economists believe. Not only are U.S. products becoming more competitive overseas, but imports into the U.S. are restricted because of price, and U.S. goods likely will fill any void created here. Most trade experts say that in third-party countries, where U.S. goods compete most fairly with goods from other

Chemical industry leaders for the second quarter . . .

Sales

Rank 1986		$ Millions	Rank 1985
1	Dow Chemical	$2904.0	1
2	Monsanto	1869.0	3
3	Union Carbide	1738.0	2
4	W. R. Grace	1410.5	4
5	PPG Industries	1200.0	5
6	American Cyanamid	1027.0	6
7	Chesebrough-Pond's	800.5	9
8	B. F. Goodrich	759.1	7
9	Celanese	743.0	8
10	Hercules	690.8	10

Earnings[a]

	$ Millions	Rank 1985
Dow Chemical	$227.0	1
Monsanto	148.0	2
PPG Industries	91.8	3
Hercules	60.1	10
American Cyanamid	56.5	11
Rohm & Haas	55.9	6
Celanese	55.0	5
Ethyl Corp.	45.1	8
Chesebrough-Pond's	44.6	13
Union Carbide	43.0	4

Profitability

	Earnings as % of sales	Rank 1985
International Flavors	14.9%	1
Freeport-McMoRan	12.1	2
Ethyl Corp.	11.1	4
Loctite	10.9	9
Rohm & Haas	9.8	11
Hercules	8.7	16
Monsanto	7.9	10
Dow Chemical	7.8	15
Petrolite	7.8	5
PPG Industries	7.7	7

. . . and for the first six months of 1986

Sales

Rank 1986		$ Millions	Rank 1985
1	Dow Chemical	$5756.0	1
2	Monsanto	3614.0	3
3	Union Carbide	3358.0	2
4	W. R. Grace	2661.0	4
5	PPG Industries	2300.0	5
6	American Cyanamid	1944.9	6
7	Chesebrough-Pond's	1607.5	10
8	Celanese	1490.0	8
9	B. F. Goodrich	1487.9	7
10	Hercules	1336.0	9

Earnings[a]

	$ Millions	Rank 1985
Dow Chemical	$402.0	1
Monsanto	266.0	2
PPG Industries	161.0	3
Celanese	106.0	5
American Cyanamid	105.6	7
Hercules	105.5	9
Rohm & Haas	94.2	6
Chesebrough-Pond's	93.7	16
Union Carbide	80.0	4
Ethyl Corp.	77.2	10

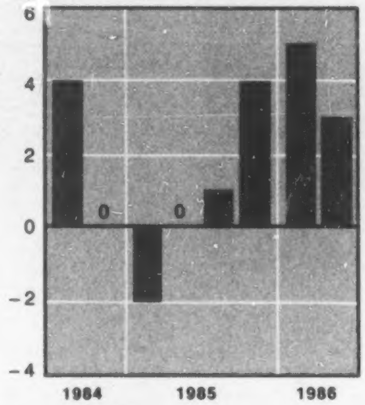
Profitability

	Earnings as % of sales	Rank 1985
International Flavors	14.9%	1
Freeport-McMoRan	11.9	2
Ethyl Corp.	9.8	5
Loctite	9.2	7
Rohm & Haas	8.5	9
Hercules	7.9	18
Petrolite	7.7	4
Nalco Chemical	7.7	3
Monsanto	7.4	13
Air Products	7.1	6
Celanese	7.1	15

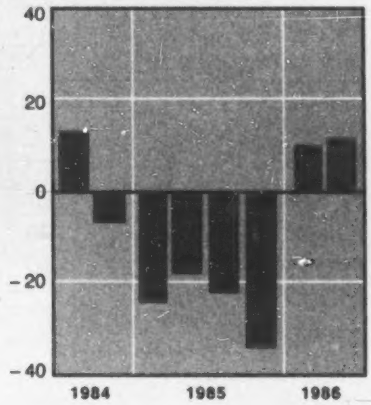
[a] After taxes. **Note:** For 30 chemical companies listed on page 12.

Chemical industry second-quarter 1986 results

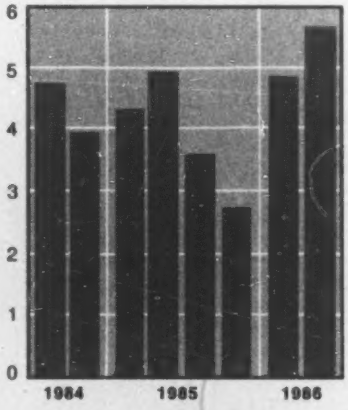
- Sales were up slightly
- Earnings rose again
- Profit margins increased
- Production climbed
- Prices tumbled


Sales

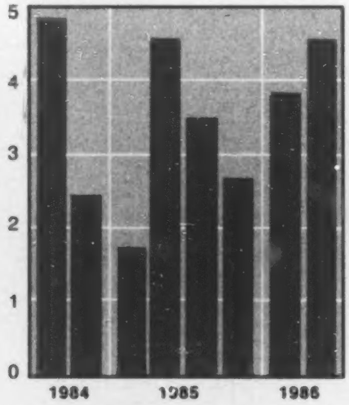
% change from year-earlier quarter


Earnings

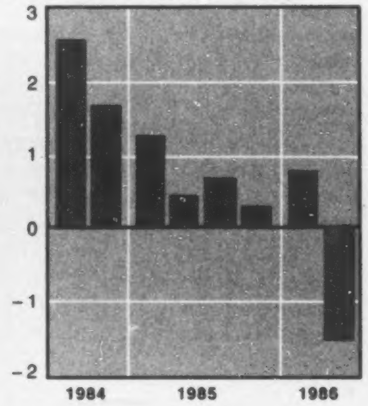
% change from year-earlier quarter


Profit margins

After-tax earnings as % of sales

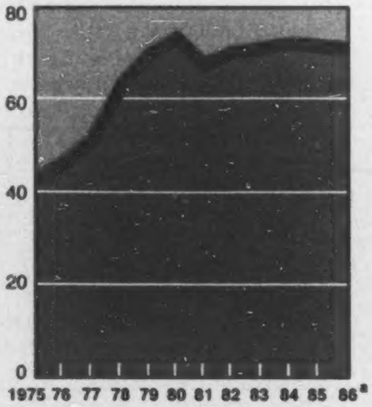

Production

% change from year-earlier quarter

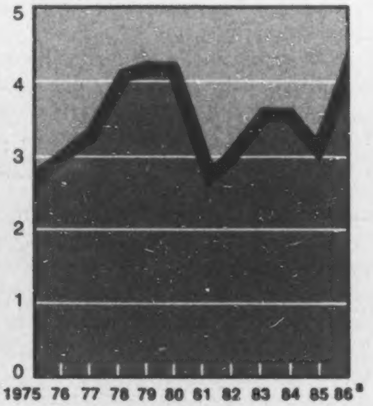

Prices

% change from year-earlier quarter

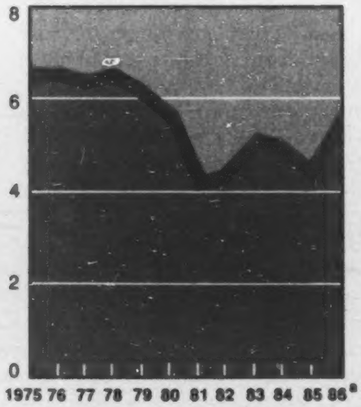
Sales in 1986 will remain near last year's level, but earnings will climb, pushing profit margins up


Annual sales

$ Billions


Annual earnings

$ Billions


Annual profit margins

After-tax earnings as % of sales

a C&EN estimates. **Note:** All sales, earnings, and profit-margin data are based on combined sales of the 30 companies listed on page 12.

For 30 major chemical firms, earnings rose an average 12% from year earlier

	SECOND-QUARTER 1986						FIRST-HALF 1986			
	Sales	Earnings[a]	Change from 1985		Profit margin[b]		Sales	Earnings[a]	Change from 1985	
	($ millions)		Sales	Earnings[a]	1986	1985	($ millions)		Sales	Earnings[a]
Air Products[c]	$ 494.9	$ 32.7	8%	−13%	6.6%	8.2%	$1003.8	$ 71.8	9%	−2%
American Cyanamid[c]	1027.0	56.5	13	75	5.5	3.5	1944.9	105.6	8	41
Celanese[c]	743.0	55.0	−5	12	7.4	6.3	1490.0	106.0	−2	25
Chemed	103.3	4.6	11	6	4.4	4.7	197.6	10.5	9	−14
Chesebrough-Pond's[c]	800.5	44.6	3	114	5.6	2.7	1607.5	93.7	37	178
Crompton & Knowles	64.7	2.6	5	11	3.9	3.7	126.8	4.5	8	30
Dow Chemical[c]	2904.0	227.0	−3	46	7.8	5.2	5756.0	402.0	0	52
Essex Chemical	60.8	3.9	3	11	6.4	6.0	111.5	6.4	7	9
Ethyl Corp.	406.0	45.1	0	25	11.1	8.9	784.0	77.2	0	20
First Mississippi	64.2	2.0	−14	−65	3.1	7.8	129.7	4.3	−9	−56
Freeport-McMoRan	161.1	19.4	−16	−8	12.1	11.0	326.0	38.6	−20	−15
H. B. Fuller	132.8	5.3	15	52	4.0	3.0	252.0	8.1	12	54
B. F. Goodrich[c]	759.1	8.7	−8	−30	1.1	1.5	1487.9	−13.5	−7	def
W. R. Grace[c]	1410.5	3.4	3	−90	0.2	2.5	2661.0	0.3	4	−99
Hercules[c]	690.8	60.1	−1	77	8.7	4.9	1336.0	105.5	0	51
International Flavors	162.1	24.1	25	26	14.9	14.8	310.1	46.2	24	25
International Minerals[c]	434.1	−18.0	31	def	def	3.3	850.6	−20.2	14	def
Loctite	73.9	8.1	23	76	10.9	7.7	140.8	12.9	24	45
Lubrizol	259.0	19.0	5	7	7.3	7.2	533.9	36.4	7	−2
Monsanto[c]	1869.0	148.0	15	19	7.9	7.6	3614.0	266.0	11	26
Nalco Chemical	184.0	14.1	11	−17	7.6	10.2	362.5	28.1	10	−13
National Distillers[c]	530.8	11.4	4	185	2.1	0.8	1162.3	32.2	7	31
Olin[c]	440.8	14.7	−4	7	3.3	3.0	892.2	40.0	−11	55
Pennwalt	289.3	11.4	8	−11	3.9	4.8	393.9	25.4	12	29
Petrolite	74.6	5.8	−3	−12	7.8	8.6	150.4	11.6	−2	−15
PPG Industries[c]	1200.0	91.8	9	3	7.7	8.1	2300.0	161.0	5	−5
Reichhold Chemicals	212.7	3.0	−10	49	1.4	0.9	422.4	4.0	0	−10
Rohm & Haas[c]	569.0	55.9	3	35	9.8	7.5	1109.8	94.2	0	15
Union Carbide[c]	1738.0	43.0	0	−48	2.5	4.8	3358.0	80.0	0	−40
Witco	347.4	17.4	−6	18	5.0	4.0	691.0	31.5	−6	22
Total 15 largest companies[d]	**$15611.5**	**$ 834.8**	**3%**	**12%**	**5.3%**	**4.9%**	**$30574.0**	**$1524.6**	**4%**	**13%**
Second 15 companies	**$ 2595.8**	**$ 185.7**	**2%**	**9%**	**7.2%**	**6.7%**	**$ 4932.4**	**$ 345.8**	**2%**	**6%**
GRAND TOTAL[d]	**$18,207.3**	**$1020.5**	**3%**	**12%**	**5.6%**	**5.2%**	**$35,506.4**	**$1870.4**	**4%**	**12%**

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. c One of 15 largest companies. d 12-month running data exclude Dow because of large nonrecurring item in fourth-quarter 1985 results. nm = not meaningful. def = deficit.

countries, foreign producers still may have an advantage because of discounting and home country government subsidies. But, they say, these will disappear over time as it becomes increasingly expensive to prop up those markets.

The falling crude oil price also has helped considerably. The results of this were seen initially at the end of the first quarter, but they have accelerated in the second quarter. As oil prices fall, petrochemical producers are receiving a real cost break for feedstocks. Although the price drop in oil has caused product prices in the chemical industry to fall, feedstock costs have fallen even more rapidly, thereby providing considerable earnings leverage to the industry.

As a result of the underlying economic activity, the U.S. chemical industry in the second quarter performed well, continuing the earnings advance begun in the first three months of this year.

For 30 major chemical companies surveyed by C&EN, earnings increased an average 12% from a year earlier to a total of $1.02 billion. Sales increased 3% to a combined $18.2 billion, raising profit margins (after-tax earnings as a percentage of sales) to a much more respectable 5.6% from 5.2% in second-quarter 1985.

For the period, the larger, more diversified chemical companies outperformed the smaller companies in terms of sales and earnings growth, but not profit margins. The 15 larger firms increased earnings 12%, the same as the total group, to a combined $835 million on a 3% sales increase to $15.6 billion.

Earnings for the 15 smaller firms increased 9% in the quarter to a combined $186 million on a 2% growth in sales to $2.60 billion.

Profit margins for the larger companies averaged 5.3%, up from 4.9% a year earlier, but margins for the smaller companies averaged 7.2%, up from 6.7% in last year's second quarter.

For the first six months of this

FIRST-HALF 1986		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1985		Profit margin[b]	
1986	1985	Sales	Earnings[a]	1986	1985
7.0%	8.0%	10%	5%	7.4%	7.7%
5.4	4.2	−1	4	4.7	4.5
7.1	5.6	−5	34	6.7	4.8
5.3	6.8	8	14	4.8	4.5
5.8	2.9	47	60	3.8	3.5
3.6	3.0	7	19	3.6	3.2
7.0	4.6	2	nm	nm	3.7
5.8	5.7	6	−19	4.5	5.9
9.8	8.2	−3	9	9.7	8.7
3.3	6.8	−2	−62	2.6	6.7
11.9	11.2	−23	−27	11.0	11.5
3.2	2.3	8	32	3.3	2.7
def	0.9	−5	def	def	0.9
0.0	1.6	−9	−47	1.1	1.9
7.9	5.2	−2	−2	6.6	6.6
14.9	14.7	18	19	14.1	14.0
def	5.6	1	def	def	6.2
9.2	7.8	15	−2	8.7	10.3
6.8	7.4	4	−8	6.4	7.3
7.4	6.5	11	−28	3.3	5.1
7.7	9.8	8	−9	9.3	11.0
2.8	2.3	8	46	2.8	2.1
4.5	2.6	−11	−1	3.2	2.8
6.4	5.6	2	−67	1.5	4.7
7.7	8.9	0	−26	6.7	9.0
7.0	7.7	5	−7	6.6	7.4
1.0	1.1	4	def	def	2.1
8.5	7.4	0	5	7.5	7.1
2.4	4.0	−13	−40	2.2	3.2
4.6	3.5	−5	10	4.4	3.8
5.0%	**4.6%**	**0%**	**−15%**	**3.6%**	**4.2%**
7.0%	**6.7%**	**0%**	**−11%**	**6.1%**	**6.9%**
5.3%	**4.9%**	**0%**	**−14%**	**4.0%**	**4.6%**

year, earnings for the 30 companies rose 12% from last year's first half to a combined $1.87 billion on a sales increase of 4% to $35.5 billion. For the 15 larger firms, first-half earnings climbed 13% to a combined $1.52 billion, and sales increased 4% to $30.6 billion. And for the 15 smaller companies, earnings increased 6% to $346 million, and sales rose 2% to $4.93 billion.

First-half profit margins for the total group rose to 5.3% from 4.9% in first-half 1985. For the larger companies, profit margins averaged 5.0% in the first half (compared with 4.6% a year earlier), and for the smaller firms, margins averaged 7.0% (compared with 6.7% in 1985's first half).

Had it not been for poor results by a few companies, the earnings increase in the quarter would have been much greater. Some of these, such as International Minerals and W. R. Grace, were affected by the continuing slump in fertilizer markets. But one big factor in moderating the earnings rise was Union Carbide, which had a $40 million, or 48%, decline in earnings in the quarter brought on by its defense against the takeover attempt by GAF last year. Without Carbide, earnings from the other 29 companies averaged an 18% increase over the same period in 1985.

Carbide's decline was brought on by a $95 million increase in pretax interest expense in the quarter and a nonrecurring gain of $27 million pretax in the second quarter of 1985. If those two items could be eliminated, Carbide's pretax income from continuing operations in the second quarter could have been $166 million, almost double the $89 million in the second quarter last year.

The positioning of companies for future earnings growth got a lot of comment from corporate executives. For instance, Richard J. Mahoney, chairman and chief executive officer of Monsanto, says: "Monsanto's second-quarter results clearly reflect an enhanced level of profitability vs. last year's second quarter. The substantial cost-cutting and overhead reductions that occurred last year are paying off in terms of improving profit trends for the chemical company's higher-value-added products. Further, Monsanto's core chemical businesses continue to benefit from lower manufacturing costs."

At Goodrich, chairman John D. Ong says, "Our businesses performed as expected during the second quarter, and we are beginning to see the positive results of our restructuring program. ... At this point we are making progress in transforming Goodrich into a significantly different company. After the formation of Uniroyal Goodrich Tire Co., nearly 80% of our revenues will come from chemicals, with the remainder from aerospace and industrial rubber products."

The improvement in international markets helped some of the companies. Dow executive vice president Robert M. Keil comments, "Business activity worldwide was relatively strong, with Dow U.S.A.'s performance and that of Dow Pacific and Dow Brazil being especially positive. Global volume remained high in response to demand increases."

Borden chairman Eugene J. Sullivan notes that operating income from the company's worldwide chemical division surged almost 51%. Overseas, he says, the divi-

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 37 oil and diversified companies, each with more than $200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 40% of its sales in chemicals, and its chemical operations must be the largest single portion of the total operations. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Earnings plummeted for oil companies, but were varied for diversified firms

	Chemical sales as % of total	SECOND-QUARTER 1986						FIRST-HALF 1986					
		Sales	Earnings[a]	Change from 1985		Profit margin[b]		Sales	Earnings[a]	Change from 1985		Profit margin[b]	
		($ millions)		Sales	Earnings[a]	1986	1985	($ millions)		Sales	Earnings[a]	1986	1985
OIL AND GAS COMPANIES													
American Petrofina	15%	$ 476.0	$ 4.4	−19%	−72%	0.9%	2.7%	$ 983.4	$ −35.3	−16%	def	def	1.6%
Amoco	14	5,011.0	253.0	−31	−58	5.0	8.2	10,929.0	584.0	−24	−46%	5.3%	7.5
Ashland	18	1,800.0	80.0	−14	33	4.4	2.9	3,600.0	119.0	−8	61	3.3	1.9
Atlantic Richfield	17	3,549.0	150.0	−39	−63	4.2	7.0	7,836.0	449.0	−32	−42	5.7	6.7
Chevron	6	6,800.0	297.0	−42	−14	4.4	3.0	15,600.0	535.0	−36	−24	3.4	2.9
Exxon	12	17,981.0	1137.0	−22	−11	6.3	5.5	40,224.0	3074.0	−13	21	7.6	5.5
Kerr-McGee	14	625.7	3.2	−26	−92	0.5	4.8	1,344.6	25.3	−19	−63	1.9	4.2
Mobil	5	12,236.0	386.0	−14	−6	3.2	2.9	26,113.0	883.0	−11	21	3.4	2.5
Occidental Petroleum	10	3,827.2	38.7	4	−72	1.0	3.7	7,458.0	112.9	1	−49	1.5	3.0
Phillips Petroleum	15	2.340.0	52.0	−41	−56	2.2	2.9	5.450.0	148.0	−31	−36	2.7	2.9
Shell Oil	18	4,164.0	219.0	−18	−35	5.3	6.6	8,830.0	495.0	−10	−22	5.6	6.4
Standard Oil (Ohio)	5	2,606.0	123.0	−25	−68	4.7	11.2	5,511.0	376.0	−18	−49	6.8	11.0
Texaco	3	7,900.0	185.0	−32	−33	2.3	2.4	17,500.0	513.0	−26	6	2.9	2.0
Unocal (Union Oil)	11	2,103.0	34.6	−27	−71	1.6	4.2	4,382.9	104.8	−23	−65	2.4	5.3
Williams Cos.	24	507.0	7.2	−30	−60	1.4	2.5	1,303.4	21.4	−26	−54	1.6	2.6
DIVERSIFIED MANUFACTURERS													
Allied-Signal	24	2,943.0	143.0	22	8	4.9	5.5	5,852.0	329.0	20	23	5.6	5.5
Aluminum Co. of America	5	1,232.2	53.3	−10	−5	4.3	4.1	2,409.5	54.7	−10	−13	2.3	2.3
Big Three	49	164.9	10.5	−22	−15	6.4	5.9	368.5	24.4	−9	2	6.6	5.9
Borden	33	1,236.9	52.0	4	12	4.2	3.9	2,373.3	88.6	5	10	3.7	3.6
Borg-Warner	28	933.4	51.0	9	4	5.5	5.7	1,828.9	100.4	11	7	5.5	5.7
Cabot	51	310.1	13.1	−12	−11	4.2	4.2	650.3	30.8	−6	−11	4.7	5.0
Du Pont	38	6,909.0	456.0	−6	−41	6.6	4.4	14,078.0	860.0	−3	85	6.1	3.2
Eastman Kodak	22	2,694.6	155.6	10	−5	5.8	6.7	5,040.0	247.1	10	−12	4.9	6.1
Eli Lilly	22	879.3	125.7	16	14	14.3	14.5	1,867.6	198.3	12	−27	10.6	16.3
Emhart	15	527.9	19.8	17	−26	3.8	5.9	1,037.5	37.8	19	−10	3.6	4.8
Engelhard	26	492.8	15.4	3	50	3.1	2.1	1,019.1	26.8	−3	22	2.6	2.1
FMC	39	807.4	49.2	−8	−10	6.1	6.2	1,559.7	74.9	−5	−24	4.8	6.0
GAF	49	198.3	22.2	5	44	11.2	8.2	374.3	37.2	3	40	9.9	7.3
General Electric	8	7,790.0	621.0	14	5	8.0	8.6	13,670.0	1158.0	5	5	8.5	8.4
Georgia-Pacific	4	1.929.0	86.0	8	28	4.5	3.7	3,533.0	116.0	5	0	3.3	3.4
Kaiser Aluminum	13	554.2	−29.6	7	def	def	def	1,084.9	−22.4	10	def	def	def
Koppers	44	370.9	17.8	−2	80	4.8	2.6	627.9	17.2	−1	def	2.7	def
Merck	13	1,005.0	173.2	15	26	17.2	15.7	1,926.1	331.0	11	23	17.2	15.5
3M	15	2,185.0	198.0	12	14	9.1	8.9	4,254.0	379.0	10	10	8.9	8.9
Morton Thiokol	35	490.5	30.0	−9	7	6.1	5.2	1,009.0	66.1	6	10	6.6	6.3
NL Industries	40	315.9	−34.4	−12	def	def	1.9	675.2	−35.4	−2	def	def	1.6
Pfizer	10	1,117.9	156.1	12	14	14.0	13.7	2,150.0	325.0	10	14	15.1	14.6
Tyler	41	248.4	4.3	3	−24	1.7	2.3	478.6	7.9	4	−10	1.7	1.9
U.S. Steel	6	4,200.0	−87.0	−22	def	def	2.8	8,851.0	−86.0	−15	def	def	3.2
Vulcan Materials	30	256.6	31.7	−2	19	12.4	10.2	457.2	38.6	−1	14	8.4	7.4

a From continuing operations excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. def = deficit.

sion's operations in southern Latin America had a major turnaround, "led by our chemical subsidiaries in Brazil and Argentina." He also says that profits for European chemical operations were up more than 75% although profits for northern Latin America were about the same as they were a year ago.

Borg-Warner says its chemicals continued strong in the second quarter, particularly in Europe.

The dark cloud over the chemical industry continued to be agricultural chemicals—particularly fertilizers, with mixed results from pesticide operations. For example, James R. Moffett, chairman of Freeport-McMoRan, explains that "demand for agricultural minerals continues to be limited by surplus grain stocks, low farm product prices, and the depressed state of the farm economy. Nevertheless, we are confident that our highly efficient, low-cost agricultural minerals operations will continue to perform satisfactorily."

Chemical earnings rise rapidly for most energy companies

If the oil companies had not had chemical operations this year, they would have been in much worse shape than they were. While overall earnings at the major oil companies were falling rapidly in the second quarter, chemical earnings were helping to save the bottom line. The same holds true for the entire first half.

As oil prices declined, earnings from these companies' oil operations fell drastically. But those same falling oil prices make petrochemical feedstocks much cheaper, and since the oil companies are predominantly producers of petrochemicals as far as their chemical operations go, those earnings soared.

For a group of seven oil companies that are also major chemical producers, earnings from chemicals in the second quarter rocketed an aggregate 71%. For the first half, total chemical earnings for the seven companies more than doubled, up 105%.

At Exxon, where chemical net earnings increased 71%, chairman C. C. Garvin Jr. said, "Petroleum product and chemical prices have fallen less rapidly than crude costs. This fact, combined with the weakening of the dollar, has had a significant positive impact on margins in refining, marketing, and chemicals." Chemical margins were improved both in the U.S. and abroad, the company says.

That was echoed at Mobil, which had a 78% earnings increase in the second quarter to $32 million. The company says that improved petrochemical and plastics margins and volumes, both in the U.S. and overseas, provided most of the income increase.

Of the seven companies, Chevron and Shell more than doubled their previous year's earnings. And large gains were posted by Mobil (78%), Atlantic Richfield (64%), and Amoco (40%). Texaco had the lowest increase on the list and even it was a healthy 20%.

For some of the oil companies not reporting chemical net earnings, the second quarter seemed just as good. Standard Oil (Ohio) says chemical earnings improved over last year's second quarter in the acrylonitrile business because of better margins. For industrial products earnings improved primarily because of higher volumes and prices for titanium dioxide slag.

Phillips Petroleum says that its chemical operations' higher earnings resulted from lower feedstock and operating costs, but these were partially offset by lower prices.

Only Williams, with its long-suffering fertilizer operations, seems to have room to complain. Its Agrico Chemical Co. had a second-quarter operating profit of $5.6 million, down from $17.6 million in the same period last year. The firm says sales volumes in North America were down 31% and prices were down for most products.

EARNINGS ON CHEMICAL OPERATIONS

	Second quarter		%	First half		%
$ Millions	1986	1985	change	1986	1985	change
Amoco	$ 70.0	$50.0	40%	$142.0	$ 99.0	43%
Atlantic Richfield	41.0	25.0	64	67.0	46.0	46
Chevron	31.0	15.0	107	62.0	35.0	77
Exxon	123.0	72.0	71	238.0	117.0	103
Mobil	32.0	18.0	78	64.0	11.0	482
Shell	76.0	35.0	117	148.0	49.0	202
Texaco	12.0	10.0	20	18.0	3.0	500

In the second quarter, W. R. Grace, whose total earnings declined 90%, suffered a $9 million loss in agricultural chemicals, compared with a $1.4 million loss in the same period in 1985. Grace says its agricultural chemicals business was plagued by persistent poor pricing conditions, excessive inventories, and lower sales volume.

But all was not bad in the agricultural market. Some pesticides turned in better results, although that was spotty. Monsanto's Mahoney says that because the U.S. corn and soybean acreage was reduced this year, Lasso herbicide finished the planting season down from last year. A significant volume improvement, however, for Roundup in the first half of 1986 more than offset weak volumes for Lasso. Currency translation gains owing to a weaker dollar also aided the worldwide profits from Roundup, which added to the overall performance of Monsanto's crop chemicals. For the quarter, operating income from the company's crop chemicals increased 15% over last year's second quarter to $154 million on a sales rise of 8%.

American Cyanamid says its agricultural group had increased sales and sharply higher operating earnings in the quarter. The performance, it says, resulted from strong worldwide sales of crop protection chemicals, particularly Scepter herbicide, which was introduced to the U.S. soybean market.

Other companies were not so fortunate with agricultural chemicals, however. PPG Industries' agricultural chemicals sales volume and prices generally trailed those of last year. Sales of Chesebrough-Pond's agricultural products unit fell 11% to $123 million. And Rohm & Haas' performance of agricultural chemicals, excluding seeds, in North America was about the same as last year.

Still, companies are optimistic about the future. Dow's Keil says, "Dow's daily sales volume, excluding feedstocks, reached its highest level in seven years this quarter, and we are entering the third quarter with an encouraging order pattern. Continuation of this trend will help buffer the normal seasonal business decline that characterizes this period and provide good momentum for subsequent gains in the remaining quarters."

Even IMC's Kennedy is optimistic about the fertilizer business. He says the firm is well positioned for a turnaround in fertilizers. "Things within our ability to control—our costs, productivity, efficiency, working capital, and the like—are in the most competitive position in our history. All that will pay off as the agricultural economy turns upward." □

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AUGUST 18, 1986
CHEMICAL & ENGINEERING
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Engineering Plastics

Competition mounts as
products proliferate /Page 21

CHEMICAL & ENGINEERING
NEWS

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AUGUST 18, 1986

News of the Week

- **Carbide says it has identified a disgruntled employee as a possible culprit in the Bhopal gas leak disaster.** Page 4
- **France's Air Liquide, world's largest industrial gas supplier, offers to buy Houston-based Big Three Industries.** Page 5
- **House votes to hold off production of binary chemical weapons until 1987.** Page 5
- **NASA selects new design for space shuttle booster rocket to eliminate problems that caused the *Challenger* explosion.** Page 5
- **NAS report on air quality inside commercial airliners recommends ban on smoking in domestic flights.** Page 6

Cover: Surgical trays are one of newest uses of polysulfone. Photo courtesy of Amoco Chemicals

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Business

U.S. synthetic fiber industry outlook is bleak with continuing imports of finished textile goods and continuing loss of share in world production and capacity. **Page 9**

Government

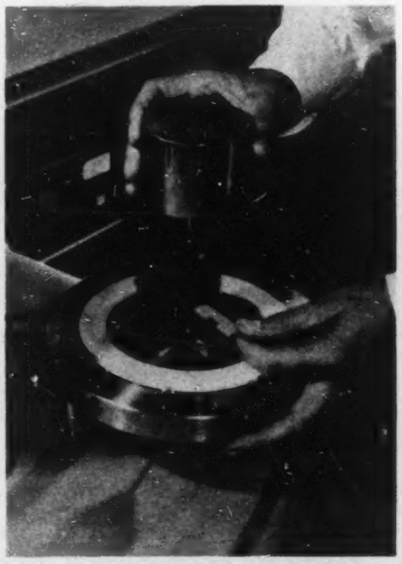
House clears majority of fiscal 1987 R&D appropriation bills; no trend in funding allocations is discernible, but several agencies would receive more R&D funds than this year. **Page 11**

Science

Study of protein structure and function is aided by recent advances in x-ray diffraction, NMR, and computing equipment, according to a recently released NAS/NAE/Institute of Medicine report. **Page 14**

Books

In "The Chemist's English" a set of witty essays offers practical advice on problems that confront chemists when they write research papers and reports. **Page 49**



Product Report

The engineering plastics industry of the 1980s is characterized by proliferation of products as well as by increased competition. **Page 21**

House Passes Fiscal 1987 R&D Appropriation Bills

Funding levels allotted to federal agencies show no trend when compared with Administration request or last year's funding level

The House has cleared fiscal 1987 R&D appropriation bills for most federal agencies. The Department of Defense is the major exception. Those bills are the vehicles used to tell federal departments and agencies just how much money they actually have to spend in any given fiscal year. It's hard to discern any overall trend for R&D in House action to date, and the Senate may well have different priorities.

The House has set the 1987 budgets for some R&D programs at levels that are below both fiscal 1986 funding and the Administration request for 1987. Other programs are funded below 1986 levels but above the request; still others are above 1986 levels but below the request. And the House has set funding for some R&D programs that is up from both 1986 funding and the Administration request.

A good example of programs in the latter category are those of the National Institutes of Health, for which the Administration had requested an overall decrease of about 4%. The House went in the opposite direction, approving a 1987 budget of $6.2 billion for NIH, 17% above fiscal 1986 funding and 21% more than requested, with all of the individual institutes sharing the largesse. The Appropriations Committee directed that the monies in the bill should be used to fund full direct and indirect costs of no fewer than 6200 new and competing renewal awards and provide support for 13,320 noncompeting research projects. The bill also contains $199 million for research on acquired immune deficiency syndrome and funds for small instrumentation grants to be used for the purchase of equipment ranging in cost from about $5000 to $60,000.

Overall funding for the Department of Energy's research programs is also up in the House bill, 8% over the request and 6% over 1986, to just over $4 billion. However, a number of research programs face budget cuts in fiscal 1987. As approved by the House, funding for geothermal R&D is down 33% to $17.9 million, solar R&D is down 22% to $113 million, nuclear R&D

House okays rise in overall R&D funding

$ Millions	1987 Appropriation	1987 Request	1986	% difference Appropriation-Request	% change 1986–87
NIH	$ 6,152.8	$ 5,079.1	$ 5,259.7	21%	17%
Energy	4,044.5	3,734.1	3,799.5	8	6
Energy supply R&D	**1,679.9**	**1,567.0**	**1,660.4**	**7**	**1**
Supporting research and technical analysis	582.7	524.0	495.4	11	18
Magnetic fusion	358.0	333.0	365.5	7	−2
Nuclear	330.9	330.9	375.7	−7	−12
Environment	249.0	272.7	223.7	−9	11
Solar	113.4	72.3	144.6	57	−22
Electric energy systems and storage	28.0	16.2	28.8	73	−3
Geothermal	17.9	17.9	26.7	—	−33
Weapons R&D	**1,155.4**	**1,239.9**	**1.015.4**	**−7**	**14**
General science and research	**738.4**	**773.4**	**665.9**	**−5**	**13**
Fossil R&D	**314.5**	**82.8**	**2,096.9**	**280**	**6**
Conservation R&D	**156.3**	**71.2**	**170.9**	**119**	**−9**
NASA[a]	3,197.0	3,184.4	2,771.5	—	15
Conduct of R&D	3,020.7	3,003.1	2,638.2	1	14
R&D facilities	166.3	181.3	133.3	−8	25
NSF[a]	1,549.3	1,685.0	1,457.4	−8	6
Research and related activities	1,333.3	1,479.0	1,294.1	−10	3
Antarctic programs	117.0	117.0	110.1	—	6
Science education activities	99.0	89.0	53.2	11	86
Commerce	1,253.7	1,070.1	1.296.6	17	−3
NOAA	1,044.7	836.5	1,097.2	25	−5
NBS	114.0	124.0	118.4	−8	−4
PTO	95.0	109.6	81.2	−13	17
USDA	945.9	882.2	889.4	7	5
Agricultural Research Service	536.7	513.0	487.0	5	10
Cooperative State Research Service	269.1	246.3	276.1	9	−3
Forest Service research	129.2	111.5	125.5	16	3
National Agricultural Library	10.9	11.4	10.8	−4	1
EPA R&D[a]	288.0	295.2	324.6	−2	−11
TOTAL	$17,431.2	$15,930.1	$15,808.7	9%	10%

[a] Funding level approved only by House Appropriations Committee. **Note:** All figures are estimates.

is down 12% to $331 million, and conservation R&D is down 9% to $156 million.

The House provided $583 million for DOE's supporting research and technical analyses (SRTA) programs in fiscal 1987, 11% more than requested and 18% more than in fiscal 1986, with all of the SRTA subprograms receiving increases over fiscal 1986 funding levels. The lone SRTA subprogram supported at less than the Administration request is chemical sciences, for which a 10% increase had been sought. The House allowed only a 4% increase to $96 million.

The total of $59 million above the budget request that the House allocated for SRTA is more than accounted for by the $70 million that the Appropriations Committee added to the request for construction projects at eight institutions. Those include $16.3 million for the Energy Research Complex at the University of South Carolina; $14.8 million for an energy demonstration project at St. Christopher's Hospital for Children in Philadelphia; $12.3 million for the Center for Nuclear Imaging Research at the University of Alabama, Birmingham; $6 million for the Center for New Industrial Materials at Iowa State University; and $4 million for the National Center for Chemical Research at Catholic University in Washington, D.C. An amendment offered on the House floor to delete funding for the projects was defeated 315 to 106.

Other funding items approved by the House include a 10% increase over current funding to $537 million for the Agricultural Research Service, a 3% decrease to $269 million for the Cooperative State Research Service, a 5% decrease to just over $1 billion for research by the National Oceanic & Atmospheric Administration, and a 4% decrease to $114 million for the National Bureau of Standards.

Awaiting a floor vote at press time was the HUD-Independent Agencies appropriation bill that sets funding for the National Science Foundation, National Aeronautics & Space Administration, and the Environmental Protection Agency. The Appropriations Committee reduced the budget request for NSF 8% to $1.5 billion, leaving it with a 6% increase over current funding levels. Still, the committee says in its report on the bill that the increase represents the largest single increase recommended in 1987 for the operating programs of any major agency carried in the bill. The request for research and related activities was trimmed 10% to $1.3 billion, a bare 3% increase over current funding. The committee says it expects NSF to apply any reductions on a relatively equal basis. However, the committee provided $99 million for NSF's science education programs, an amount that is 86% above current funding and 11% more than requested.

The committee approved a 15% increase to $3.2 billion, just slightly more then requested, for NASA's R&D programs, while cutting EPA's R&D programs 11% to $288 million, 2% less than requested. The committee cut $6 million from EPA's in-house R&D budget. In its report the committee explains its actions by saying that "the 1987 request proposes a 10% reduction in extramural research but only token cuts in internal R&D resources. The committee has made this reduction to preserve the current balance of intramural and extramural R&D until the agency [EPA] develops the necessary management tools to make research activities more responsive to program office needs and to Congress."

The committee's decisions can, of course, be reversed by the full House and by the Senate. However, rather than adding money to appropriation bills, the House has been deleting money from them, and the Senate is likely to be equally tight fisted. Given that the latest deficit estimate is $230 billion, Congress will have to slash the budget by $86 billion if the mandatory fiscal 1987 deficit target of $144 billion set by the Gramm-Rudman-Hollings law is to be met. The Senate has devised a plan for reinstating the automatic across-the-board cuts provided for in that law. The House has not yet approved the plan. But however one looks at it, fiscal 1987 is not a good year to start with a low-base budget.

Janice Long, Washington

Federal Alert—new regulations

This C&EN listing highlights regulations published in the Federal Register *from July 7 through July 31. Complete information is available on the appropriate page number.*

PROPOSED

Environmental Protection Agency—Terminates investigation of occupational exposure to toluenediamines, concluding any such risk is more appropriately handled by OSHA (July 10, page 25070).

Revises and requests comments on requirements for analysis of total contaminants in groundwater; comments by Sept. 22 (July 24, page 26632).

Recommends limiting exposures to radiofrequency radiation; comments by Oct. 28 (July 30, page 27318).

Food & Drug Administration—Implements regulations for patent extensions for human drug products, food additives, color additives under Patent Term Restoration Act; comments by Oct. 9 (July 11, page 25338).

National Oceanic & Atmospheric Administration—Regulates licenses and permits for commercial recovery of deep seabed hard-mineral resources; comments by Oct. 23 (July 25, page 26794).

Occupational Safety & Health Administration—Recommends new performance-based standards to protect laboratory workers from toxic chemicals; comments by Oct. 22 (July 24, page 26660).

FINAL

Energy Department—Sets new terms for uranium enrichment services for civilian customers to help keep U.S. competitive in world market; effective Oct. 1 (July 29, page 27132).

Environmental Protection Agency—Requires specific health-effects tests by manufacturers and processors of certain chlorinated benzenes; effective Aug. 21 (July 8, page 1986).

Allows owners of hazardous waste landfills to use "corporate guarantee" to comply with liability insurance requirements; effective Sept. 9 (July 11, page 25350).

Revises regulations on primary containment vessels, release response, and closure requirements for hazardous waste storage and treatment tank systems; various effective dates (July 14, page 25422).

Food & Drug Administration—Clarifies whether presence of sulfiting agents must be included on food labels; effective Jan. 9, 1987 (July 9, page 25012).

Nuclear Regulatory Commission—Releases policy for regulation of advanced-technology nuclear power reactors; effective Aug. 7 (July 8, page 24643).

PRODUCT
REPORT

Dow Chemical photo

Engineering Plastics: More Products, More Competition

David Webber, C&EN New York

General Electric has introduced more new engineering plastics during the past four years than in any other period in the company's history. That spurt of innovation by the engineering resins pioneer and—according to many—leader, typifies the industry in the 1980s. "We've seen more product proliferation in the past few years than ever before," says Virginia W. Donohue of GE Plastics.

This is typical of the entire business of noncommodity plastics—including resins, alloys, blends, and composites with superior properties of impact resistance, heat resistance, and stiffness. It is in a period of intense activity. Not only are manufacturers churning out more new products and more modified versions of existing products, but more companies are entering the field. To beef up their offerings, producers are devoting greater resources to their research and development and technical service operations. At the same time, they are also turning to product line acquisitions, joint ventures, licensing, and other business relationships as never before.

To the greatest extent, this surge in activity reflects the expansion of the market for materials with ever-higher performance characteristics. Between 1983 and 1984, for example, U.S. production of a cross-section of major engineering resins increased 21% to 878 million lb, according to the Society of the Plastics Industry's most recent statistics. Between 1974 and 1983, by comparison, production grew at a com-

Donohue: dividing lines are gray

pound annual average rate of less than 7%.

This growth is occurring as downstream manufacturers become increasingly willing to spend more on raw materials to answer higher performance requirements in such major end-use industries as automobiles, packaging, electronics, computers and business equipment, aerospace, and medical supplies. However, as the expanding market attracts more players, producers are finding they must be more innovative to differentiate their products from those of their competitors. Consequently, the industry trend has been not just to develop more new products but also to tailor them more to specific end uses.

Meanwhile, engineering plastic products are under price pressure from upgraded commodity resins like polypropylene, polystyrene, and acrylonitrile-butadiene-styrene (ABS), which are taking away business in applications where high-performance requirements are more marginal. As a result, engineering plastics producers are working on ways to cut the ultimate expense of using their product for customers—if not in the price of the plastic then in the cost of processing it.

At the same time that vistas of enormous new markets are opening up to producers—in the potential, for instance, for thermoplastic exterior body panels for automobiles and for rigid plastic food packaging—the promise of greatly increased use of plastics in consumer products is heightening interest in the issue of recycling. Spurred by the tremendous success of polyethylene terephthalate (PET) beverage bottles, legislators, government officials, and environmentalists are worried that vast quantities of engineering plastic waste are likely to be added in the future to the existing plastic disposal problem. They want to ensure that consumer plastic scrap is not just dumped or burned. Industry, in an effort to work out methods to reclaim the materials on a basis more economical than incinerating them for their fuel value, is examining practical problems ranging from how to collect plastic scrap to how to separate the different resin components.

As engineering plastic products have become more specialized, manufacturers have converted en masse to the "get close to the customer" creed that has become the mid-decade slogan for researchers and marketers in the chemical and polymer industries. Producers of engineering plastics—as well as manufacturers of adhesives, coatings, and other products—have been flocking to Detroit, for instance, where they are busily establishing technical service laboratories and demonstration plants in their efforts to woo the automobile makers. Companies eyeing the mammoth packaging market, where commodity resins are big but engineering plastics are still relatively tiny, are reaching beyond their immediate customers—package fabricators—in their research into market needs. Instead, they are asking food companies and, in some cases, the general public what new packaging developments would be welcome.

Eidman: trying to determine needs

"We've been trying to determine the needs of converters and end-users in both the food and nonfood areas to let them determine where we place the emphasis in our research efforts," says Richard A. L. Eidman, Du Pont product manager for Selar barrier resins and Bynel coextrudable adhesive resins, both of which are used in packaging.

Dow Chemical, a relatively recent entry in the engineering plastics field, hopes that better knowledge of downstream needs will help it catch up to GE, Du Pont, and other industry leaders. "We're looking for trends on the level of our customer's customer to help us determine what our primary customers must do," explains Robert Baughman, Dow's general manager for specialty plastics. "Now we can go through what we learn from secondary customers and try to determine if there truly is an unmet need out there or if it is just Dow's feeling that there is one."

As more products have entered the engineering plastics end-use marketplace—including engineering resins, alloys, blends, copolymers, and enhanced grades of commodity resins—producers find themselves faced with the problem of defining an engineering plastic.

"A combination of things has made the dividing lines somewhat gray," remarks GE's Donohue, who is manager of business development and the planning operation for the plastics division. "It used to be easy to divide thermoplastics between commodities and engineering resins on the basis of performance and specifications. With what is happening today in blend work, however, and with more producers, there are a lot of unresolved issues."

The lack of uniformity in the way people apply a number of basic terms does not help resolve this definitional ambiguity. The broadest definition of engineering plastics embraces everything above commodities, so to speak. In that sense, the term applies to workhorse engineering thermoplastics like polycarbonate and polybutylene terephthalate, to more specialized engineering resins like polyphenylene sulfide, polyether ether ketone, and liquid crystal polymers, and to alloys of materials like polycarbonate and polybutylene terephthalate.

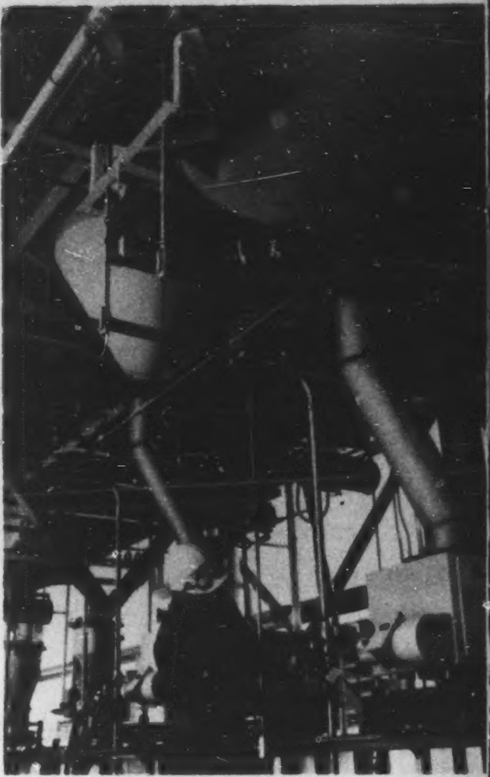
Narrower definitions separate products like polycarbonate from higher-performance plastics. At Charles H. Kline Inc., for example, all plastics are divided, for purposes of categorization, into three parts—tonnage plastics, specialty plastics, and combined materials. The Fairfield, N.J., research house drafts its definitions on the basis of price, volume, and application. Engineering thermoplastics form a subcategory of specialty plastics along with a second subcategory that Kline calls high-performance plastics.

The defining criteria break out along the following lines, according to Kline vice president Thomas E. Galvanek. Tonnage plastics, generally referred to as commodities, are characterized by high capital intensity, relatively low R&D costs, an emphasis on process development, little need for knowledge of end-use industries, great need for vertical integration in raw materials, and small product differentiation. Growth is relatively slow, and prices are generally less than $1.00 per lb.

Engineering thermoplastics, by comparison, are characterized by moderately higher R&D costs, lower capital intensity, lower sales tonnage, a greater need for knowledge of end-use industries, and less need for a raw material base. Prices typically range from $1.00 to $4.00 and more per lb.

In the Kline definition, high-performance plastics are high-risk businesses in which total demand is low but sales revenues are high, R&D costs are high, capital intensity is lower, and the need to know end-use industries is higher than in the case of commodities but lower than in the case of engineering thermoplastics. Volume growth is high, ranging from 10 to 20% per year, and prices range from $3.00 to $30 and more per lb.

Kline's third category, combined materials, includes blends, alloys, and reinforced plastics. Such businesses, Galvanek says, are characterized by low capital costs, because the equipment to produce the component materials is generally already in place. Some sort of mixer may be all that is required. But, he says, combined materials producers must acquire a thorough knowledge of their end-use markets, because they are looking for niches in which they can fill a performance gap at an intermediate price. As a result, combined materials are typically extremely tailored to a specific use, and producers must provide a great amount of technical service and development.

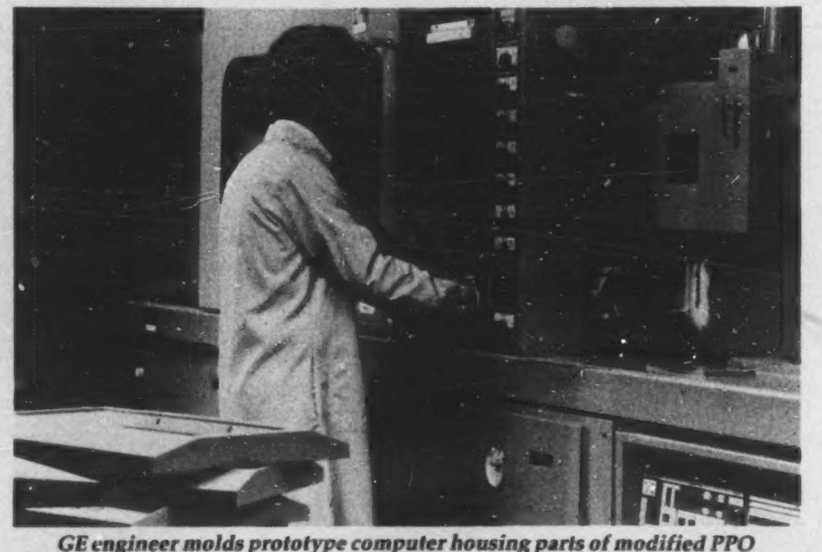


Worker processes enhanced grade of ABS at Dow Chemical's new Midland, Mich., production facility

Perhaps the least resolved aspect of the definition debate concerns enhanced grades of commodity resins. ABS, for example, is a commodity now available in versions whose performance makes them very much like engineering resins.

Dow, for example, which is trying to shift its product base in plastics from large-volume commodities to engineering thermoplastics and specialties, places both ABS and high-impact, high-gloss, and ignition-resistant grades of polystyrene alongside the company's polycarbonate and weatherable polymer lines in its engineering thermoplastics category.

At the same time that a burgeoning product mix has made definitions more vague, consumers of engineering plastics are putting increasing pressure on producers to tailor products to their precise needs. "As end-users have gotten more used to engineering plastics, they have become more sophisticated," GE's Donohue says. "They are more price- and quality-oriented. They have more knowledge about alter-



GE engineer molds prototype computer housing parts of modified PPO

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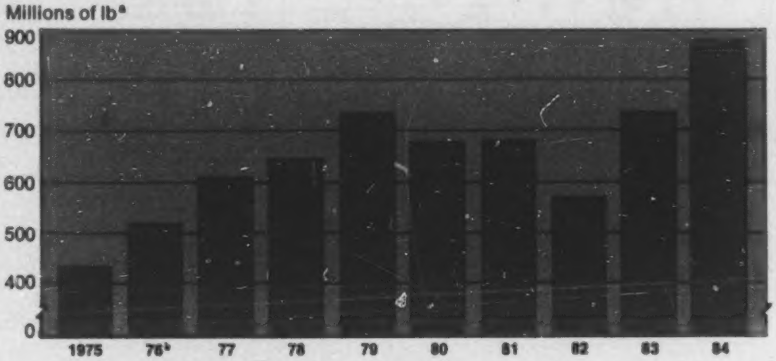
Engineering resins output has doubled since mid-1970s



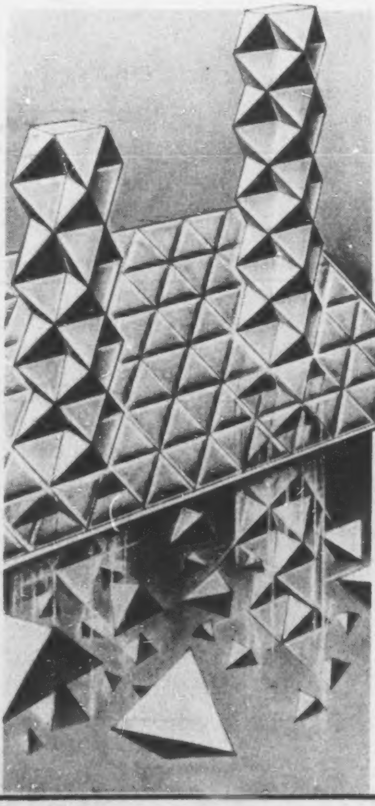
a Annual U.S. production of acetal, polycarbonate, polyphenylene sulfide, polysulfone, modified polyphenylene oxide, polyimide, and polyamide-imide engineering resins. b Estimated.
Source: Society of the Plastics Industry as compiled by Ernst & Whinney

native materials, so they have a greater ability now to make decisions between properties and price."

All these factors combined form the driving forces in the engineering plastics business today. More sophistication on the part of end-users has opened up opportunities for combined materials and upgraded commodity resins that can offer somewhat lesser but adequate performance at a lower cost. The proliferation of products that has followed both that trend and the increasing demand for the highest-performing plastic materials has created a large degree of overlap between products. A variety of plastics, for instance, may possess the required heat-resistance properties for a certain application but will differ in terms of other performance properties, processing, and price.

In this more complicated world, product differentiation has become the byword for companies. To better differentiate themselves from their competitors, engineering plastics producers have adopted two key strategies: broadening their product portfolio and bolstering their technical service operations.

The two strategies are linked by the increased need to give those more sophisticated end-users exactly what they need. A broader product portfolio means more than just offering a wider range of off-the-shelf materials to potential customers. A broader base of materials available for blending and alloying



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Lithco's magnesium alkoxides are available in hydrocarbon solutions and offer distinct advantages in the manufacture of polyolefins. Lithco also provides many other organometallics for polymerization, including alkyllithiums and dibutylmagnesium. At its new, multi-million dollar facility in North Carolina, Lithco has the capacity to custom synthesize catalytic agents to customer specifications.

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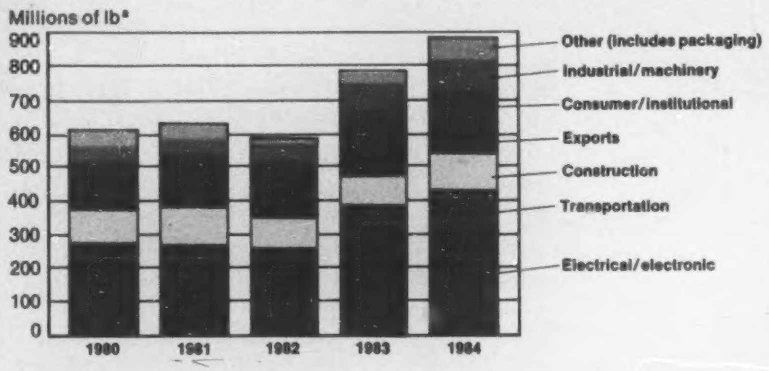
CIRCLE 24 ON READER SERVICE CARD

Electrical/electronic uses lead engineering resin markets



[a] Estimated U.S. sales and captive use for acetal, polycarbonate, polyphenylene sulfide, polysulfone, modified polyphenylene oxide, polyimide, and polyamide-imide engineering resins.
Source: Society of the Plastics Industry

makes it easier to tailor products to meet specific requirements.

"We are increasingly called on to tailor materials to customer needs," points out James T. Hill, manager for electronics in Du Pont's polymer products department. "A key strength for us is that we have a wide spectrum of materials to draw from."

The job of properly directing that strength at the marketplace falls to the technical service operation. [illegible] Du Pont, as at other companies, such services have been substantially expanded in recent years.

"Because of the broad proliferation of products and the significant areas of overlap between different polymer families, we are focusing heavily on the area of providing more than just a bag of resin," says John F. Wahl, national development manager for the engineering polymers business at Du Pont. "We're offering a full range of services: design support, engineering support, prototyping, and analysis of a product's economics, all the way to processing and fabrication. It's a complete systems approach."

The growth of the service element in the engineering plastics business is exemplified by the stampede of producers to establish new or expand existing technical service centers in the Detroit area in the past two years. Du Pont, for example, is building a multimillion-dollar technical service laboratory at its one-year-old corporate automotive

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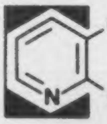

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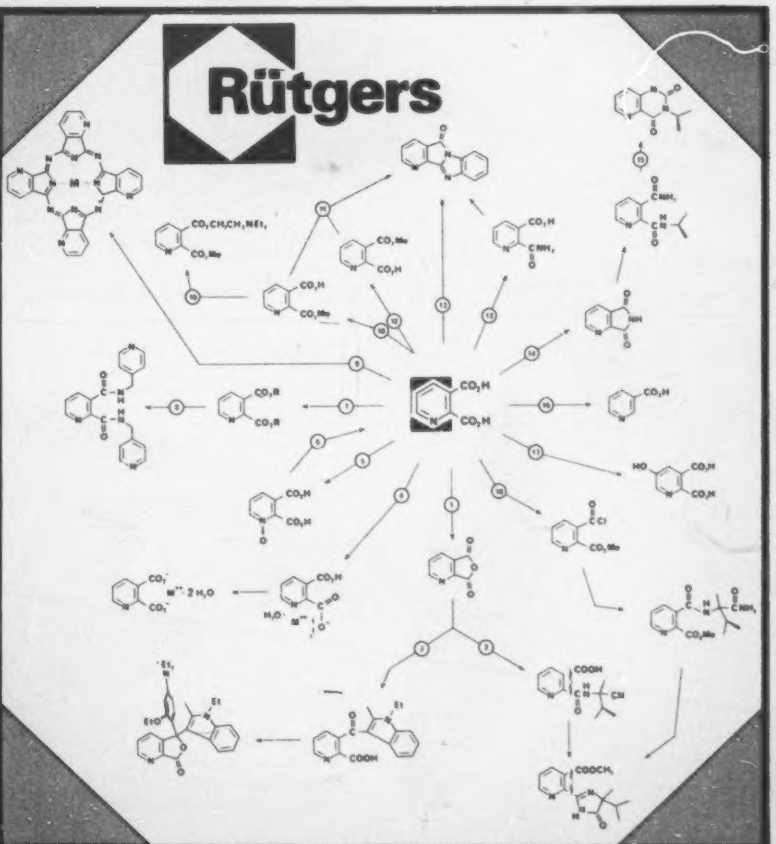


CIRCLE 29 ON READER SERVICE CARD

Engineering resins are generally used in conditions of high heat, impact, or moisture

Resin	Typical applications
Acetal	Sinks, faucets, electrical switches, gears, aerosol bottles, meat hooks, lawn sprinklers, ballcocks, shaver cartridges, zippers, telephone push buttons
Polycarbonate	Helmets, power tool housings, battery cases, safety glass, automobile lenses, 5-gal bottles
Polyphenylene sulfide	Electrical connectors, coil forms, lamp housings
Polysulfone	Electrical connectors, meter housings, coffee makers, camera bodies, automobile switch and relay bases, light-fixture sockets, fuel cell components, battery cases, medical supplies
Modified polyphenylene oxide	Automobile dashboards, pumps, shower heads, plated automobile grilles and trim, appliance housings, wiring splice devices, protective shields
Polyimide	Radomes, printed circuit boards, turbine blades
Polyamide-imide	Valves, gears, pumps, high-temperature magnet wire enamels

Source: Society of the Plastics Industry

development center in Troy, Mich., for application development of engineering polymers. The lab, due to be completed late in 1987, will include a 4000-ton injection molding machine, the sort of investment that companies are now making in their efforts to woo automobile design engineers.

In June, Celanese Engineering Resins, a subsidiary of Celanese, announced it will open an automotive development center in the Detroit area early next year. Celanese says that the automotive industry is the largest single market for its existing engineering thermoplastics—Celcon acetal copolymer, nylon, and Celanex thermoplastic polyester. The company also expects the auto industry to be a major user of a group of new resins that Celanese has either developed, acquired, or licensed in the past two years.

The new center will contain design and analytical laboratories with capabilities for computer-aided design and finite element analysis. There also will be injection-molding equipment and a parts-testing lab for end-use evaluation.

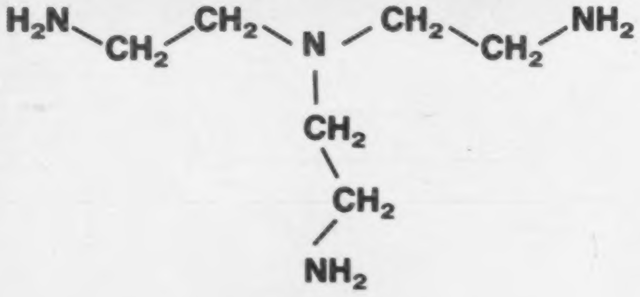
"Given the size of the market, and considering the expanded line of materials we're now offering, we definitely need a stronger presence in Detroit," explains John B. Downard, general manager of Celanese Engineering Resins. "The automotive technical center will do just that."

Earlier this year, Monsanto established an automotive marketing group in Detroit and is planning to build an automotive support facility by sometime in 1987. "Issues and opportunities relating to the automotive market are now addressed here in Detroit," says William J. Ginter, director of the new group. "Sales, marketing, and development personnel for plastic products sold to the automotive industry will now report directly to this office."

The other key element in the product differentiation strategy—broadening product portfolios—has also resulted in a flurry of activity in recent months. That activity has featured, as well as new product introductions, a surge in acquisitions, joint ventures, licensing agreements, and other business arrangements.

Celanese Engineering Resins presents a good example of a company moving rapidly to broaden its product line through a variety of measures. Last month, the company purchased the engineering resins business of GAF Corp. for an undisclosed amount. The GAF lines consist of polybutylene terephthalate (PBT) and thermoplastic polyester elastomers.

Unlimited Reactions



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CIRCLE 34 ON READER SERVICE CARD

Most resin types have just a handful of producers

Company	Location	Tradename	Annual capacity[a] (millions of lb)
Acetal			
Celanese	Bishop, Tex.	Celcon	145
Du Pont	Parkersburg, W.Va.	Delrin	135
Arylate			
Amoco Chemicals[b]	Marietta, Ohio	Ardel	13
Celanese[c]	Grand Island, N.Y.	Durel	na
	Corpus Christi, Tex.	Durel	na
Polybutylene terephthalate			
Celanese	Bishop, Tex.	Celanex	70
	Calvert City, Ky.[d]	Gafite, Gaftuf	10
General Electric	Mt. Vernon, Ind.	Valox, VCT	130
Polycarbonate			
Dow Chemical	Freeport, Tex.	Calibre	30
General Electric	Mt. Vernon, Ind.	Lexan	300
Mobay	Cedar Bayou, Tex.	Merlon	160
Polyether ether ketone			
Amoco Chemicals[b]	Marietta, Ohio	Kadel	na
ICI Americas	Wilmington, Del.	Victrex	>1
Polyimide and polyamide-imide			
Amoco Chemicals	Joliet, Ill.	Torlon	na
Du Pont	Beaumont, Tex.	Kapton	na
	Circleville, Ohio	Kapton	na
	Newark, Del.	Vespel	na
General Electric	Mt. Vernon, Ind.	Ultem	na
Polyphenylene oxide			
General Electric	Selkirk, N.Y.		na
Polyphenylene sulfide			
Celanese[e]	na	Fortron	na
Phillips Chemical	Borger, Tex.	Ryton	12
Polysulfone			
Amoco Chemicals[b]	Marietta, Ohio		20
ICI Americas	New Castle, Del.		>1

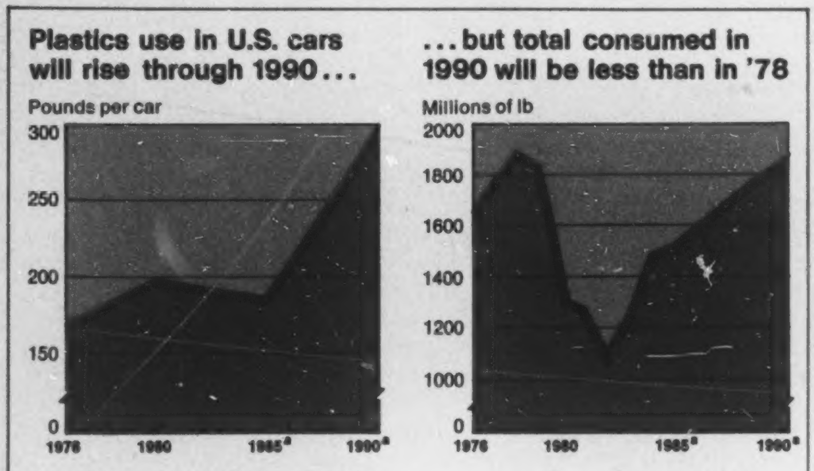
a Estimated. b Purchased from Union Carbide in June 1986. c Purchased from Occidental Chemical in May 1985. d Purchased from GAF in July 1986. e Currently selling material imported from Kureha Chemical of Japan. Plans to build U.S. plant in future. **Note:** Representative list of producers. na = not available. **Source:** SRI International

Last month, Celanese also signed an agreement with Kureha Chemical Industry Co., of Japan, giving Celanese exclusive North American sales rights as well as partial rights in Europe and Latin America to Kureha's polyphenylene sulfide (PPS) engineering resin. The arrangement makes Celanese the first U.S.-based competitor for Phillips Chemical's Ryton PPS resin. Initially, Celanese will market PPS using

Polyphenylene sulfide use to grow 15% annually

Millions of lb	Consumption 1986[a]	Share of total	Consumption 1996[a]	Share of total	Annual growth rate, 1986–96
Electrical/electronics	3.2	33%	12.5	30%	15%
Mechanical/industrial	2.3	23	8.5	20	14
Appliance	0.9	9	2.2	5	9
Transportation	0.9	9	4.0	10	15
Chemical processing	1.0	10	3.3	8	13
Miscellaneous industrial	1.0	10	2.2	8	12
Powder uses	0.5	5	0.8	2	5
Composites	0.1	1	2.0	4	35
Fibers	—	—	1.0	2	—
Film/sheet	—	—	4.5	11	—
TOTAL	9.9	100%	42.6	100%	15%

a Estimated. Source: Celanese



a Estimate. **Source:** Business Communications Co.

resin imported from Kureha, but once sales become large enough, Celanese will build a U.S. production facility in cooperation with the Japanese firm, says Celanese Engineering Resins vice president Thomas C. Bohrer.

Also last month, Celanese established a sales, marketing, and technical support company for engineering plastics in West Germany. The move reflects the increasingly global nature of the engineering plastics industry.

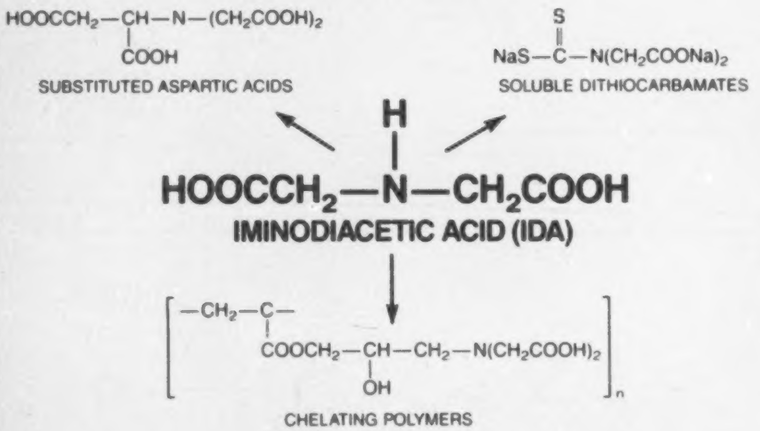
In a different type of arrangement, General Electric Plastics and PPG Industries last month formed a 50/50 joint venture called Azdel Inc. to make composites by combining PPG's expertise in glass-reinforced polypropylene sheet with GE's engineering plastics know-how. Although not so limited, the venture is seen as an intensification of GE's effort to come up with an engineering plastic-based material that Detroit could choose to replace both stamped steel and thermoset materials like fiber-reinforced polyester in large exterior auto panels.

"We see more possibilities of partnerships and joint ventures in our cards," remarks GE's Donohue. "The premise is that if we share expertise, we all gain more. The PPG venture is an excellent case in point."

In the acquisition arena, Amoco Chemicals' subsidiary Amoco Performance Products closed its purchase of Union Carbide's engineering polymers and advanced composites businesses in June. Carbide needed cash to pay off debts incurred by its defense against GAF's takeover attempt last December, while Amoco Chemicals, according to president Robert D. Cadieux, wanted to grow "in areas that are compatible with our current chemical operations and in which we have a long-range strategic interest."

The acquisition made Amoco Performance Products in a stroke a major player in the engineering plastics business. Previously, the company's presence was greatly based on one product—Torlon, a polyamide-imide resin used in composite form in racing car engines, fasteners in the space shuttle, and a developmental hydraulic pump used by the Navy for undersea salvage. With the acquisition, Amoco gained polyarylate, polyether ether ketone, polysulfone, and other resins as well as Carbide's line of rayon-, pitch-, and polyacrylonitrile-based carbon fibers.

This willingness by companies to spend substantial amounts of money—whether to broaden product lines, to increase customer services, or both—ultimately stems from perceived opportunities in end-use markets. In the automotive industry, for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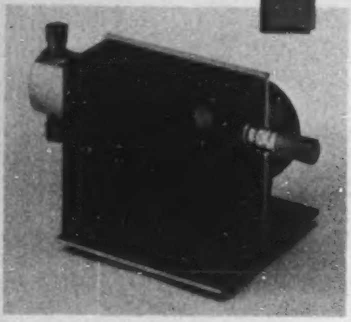

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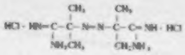

$HCl\cdot HN{=}\underset{NH_2}{C}-\overset{CH_3}{\underset{CH_3}{C}}-N{=}N-\overset{CH_3}{\underset{CH_3}{C}}-\underset{NH_2}{C}{=}NH\cdot HCl$

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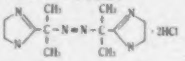

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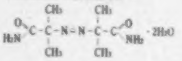

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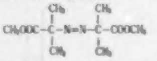

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Electrical uses dominate polysulfone resins market

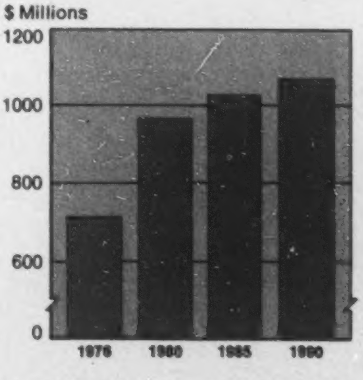
Millions of lb	Consumption	Share of total
Electrical/electronics	5.0	37%
Consumer/institutional	2.4	18
Transportation	2.0	15
Medical	1.4	10
Industrial	1.2	9
Other	1.5	11
TOTAL	13.5	100%

Note: Estimated 1985 U.S. consumption. **Source:** SRI International

example, the nature of those opportunities has been changing. A decade ago, says Nicholas G. Fountas, senior plastics consultant at Charles H. Kline, the impetus for using plastic in automobiles stemmed 80% from the desire to reduce a car's overall weight. Today, he says, the impetus is divided more or less evenly between weight-reduction and other issues like performance and processing economics.

For example, a major trend in Detroit now—as well as in the major appliance and other industries—is parts consolidation. Automobile design engineers reason that if they could replace a part assembly that involves, say, seven or eight individual cast components with a single molded part, they could cut the labor element of that part, while probably reducing weight and perhaps improving performance properties at the same time. Engineering plastics producers are hoping

Revenue growth for auto resins will be restrained



Note: Value of plastic resins in automobile applications. **Source:** Business Communications Co.

High performance pipe is growing market for Amoco Chemicals' polysulfone

to cash in on this way of thinking, which is expected to become an increasingly more important feature of the auto industry's attempts to shave costs in order to regain its competitiveness with Japanese and other overseas car manufacturers.

Another important aspect of Detroit's thinking these days is design flexibility. It costs more to retool machinery for metal than for plastic parts, but during the U.S. auto industry's heydey, when model production runs were lengthy, that cost was easily justifiable. Now, with shorter model runs, retooling is required more frequently. As a result, the ability to regear more cheaply adds a production economics rationale to the plastic producers' armamentarium of arguments.

Detroit is also scrambling to meet upcoming deadlines for corporate average fuel economy ratings. Where manufacturers originally concentrated on weight reduction to improve fuel ratings, they are now focusing increasingly on aerodynamics to do so. "A major design trend is the move to a more slippery profile," points out Kline's Fountas. "Plastics work well for sleek contours, better than most metals. It's possible to form plastics into very intricate shapes."

Plastics also continue to replace metal in under-the-hood applications, particularly as more high heat resistant materials become available. And producers are paying lots of attention to the potential for engineering thermoplastics in exterior panels. Today, there are relatively few autos made in the U.S. with plastic body panels, and all those, as is the case with General Motors' Corvette and Pontiac Fiero, are fiber-reinforced polyester. The exterior role of engineering thermoplastics, to date, has been mostly limited to smaller external parts, such as the plastic alloy bumper on the Ford Aerostar van.

Still, the promise is there. General Motors, for example, predicts that it will be manufacturing a million plastic-body automobiles in 1990, up from 150,000 this year. Engineering plastics producers want to make sure that their products play a major part in the composition of those cars. "It represents a tremendous opportunity in terms of the size of the market," says GE's Donohue.

Their increased presence in the Detroit area is testimony to that resolve. Engineering plastics makers know they must use all the tools available to them, up to and including actually fabricating automobile parts from their materials in pilot plants, to convince automotive design engineers to select their product. The opportunities alone do not explain the new round of investment in automotive-oriented facilities, however. Detroit, knowing it needs major improvements, also has

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become far more accommodating than during its more imperious past.

"General Motors, for instance, is now telling resin producers, 'If you can get us the materials at the right price, we'll give you longer contracts,'" points out Peter Mooney of Business Communications Co., a research company. "That's better than before, when the car companies were buying plastics but changing suppliers every few months. The plastics procurement policies in Detroit have become a little more humane, because of the great pressures the car companies are under. As a result, a lot of plastics companies that wouldn't go near Detroit before will now. Detroit needs their input."

In the electrical/electronic segment of the engineering plastics market—the largest at about a third of the overall business—a variety of trends are increasing demand for the highest-priced materials at one end and fostering erosion of those materials' hold on other applications at another end. One constant trend in the electrical/electronics area is size reduction. As products are made smaller, electronic engineers, to get more performance out of the same size component, place the pins on electronic interconnectors closer and closer together. That improves performance, but coincidentally creates a greater amount of heat.

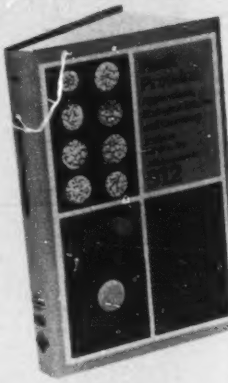
"Miniaturization of the electronic portions of devices raises the density of those devices and increases the heat load," points out Du Pont's Wahl. "So there is a need for higher-temperature performance capability."

In another trend, component assemblers are using wave and vapor-phase soldering more frequently now, further increasing the need for heat-resistance."

Those changes are altering the material choices made by the electronics industry. Early on, points out Kline consultant Fountas, interconnectors were made with thermosetting resins. Those were replaced by nylons, but when nylons began to prove too moisture-sensitive in more critical applications, glass-reinforced polybutylene terephthalate began its move toward dominance. PBT is now preeminent

CIRCLE 20 ON READER SERVICE CARD →

Plant Proteins



New!

Robert L. Ory, *Editor*
U.S. Department of Agriculture

Examines the major role plant proteins play in both human and animal diets. Discusses the use of plant proteins in both Western and traditional foods of developing countries; plant and meat protein blended foods; effects on skeletal integrity, trace mineral utilization, atherosclerosis, and cancer incidence; effects of processing on proteins; and novel, lesser known proteins. Of interest to nutritionists, food scientists, and clinicians concerned about nutritional aspects of plant proteins for humans. Also helpful to food chemists and biochemists, dieticians, and medicinal chemists concerned with nutrition.

CONTENTS
Plant Proteins: The ABCs of Peanut and Cowpea Flours • Field-Pea Flours as Protein Supplements • Vegetable Food Proteins in Traditional Foods • Uses of Soybeans as Foods • Incorporation of Cottonseed into Foods • Soy Proteins in Meat Products • Soy Protein Products in Whole Muscle Meats • Effects of Protein on Skeletal Integrity • Utilization of Trace Minerals in Humans • Nutritional Quality of Dry Beans • Corn-Glandless Cottonseed Blended Food • Influence of Protein on Serum Cholesterol • Mortality of Adventists in Relation to Diet • Protein, Starch, and Fiber from Grain Legumes • Processing and Use of Bean Flours • Winged Bean as a Source of Protein • Tropical Plants as Sources of Protein • Protein of the Sweet Potato • Cucurbit Seed Protein and Oil • Protein-Nitrogen Conservation in Yams

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in interconnectors, but, Fountas says, increasing demands for heat-resistance and dimensional stability will begin to threaten PBT's position. He sees a move toward greater use of more specialized engineering thermoplastics like polyphenylene sulfide and liquid crystal polymers in the future.

Similarly, changes in the way circuit boards are made are affecting raw material selection. There, thermoplastics are just beginning to make their presence felt. Traditionally, circuit boards have generally consisted of epoxy-glass fiber laminates limited in shape to a planar configuration. Now, with advances in high-temperature thermoplastics, circuit board manufacturers are moving toward molded, nonplanar shapes that can both perform the function of a circuit board and, in some cases, a structural part. "Circuit boards will begin to have a functional purpose, as in the housing for a motor part," points out Du Pont's Hill.

In the computer housing segment, development has run into the downturn in the computer market, coupled with the shifting overseas in recent years of a lot of molding operations as manufacturers have sought to reduce assembly costs. At the same time, many overseas molders are using plastics from other than U.S. sources. Some analysts believe that some of those manufacturing operations eventually will return to the U.S. as companies automate more, but, in the meantime, the trend has hurt producers of polycarbonate and ABS resins used in computer housings.

In the beginning of the computer boom, most housings were made of GE's Noryl resin. Noryl was priced at a premium but possessed the heat properties and flame resistance that manufacturers needed. Since then, some manufacturers have switched to enhanced grades of ABS, saving 25 to 50 cents per lb on raw material costs in the process. Now, Fountas points out, ABS is beginning to lose ground to high-impact polystyrene that has been upgraded enough to earn a high enough Underwriters Laboratory rating for computer housing applications.

"IBM will probably never use

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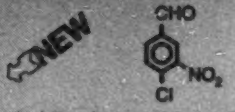
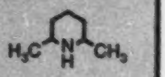
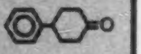


4-Chloro-3-nitrobenzaldehyde

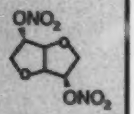


2,6-Dimethylpiperidine, cis

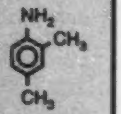


4-Phenylcyclohexanone

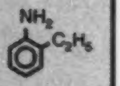
Isosorbide dinitrate (ISDN)
mixtures with lactose etc., USP XXI



2,4-Xylidine
and all other isomers



2-Ethylaniline
and 4-Ethylaniline



3,4-Methylenedioxyaniline
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CIRCLE 31 ON READER SERVICE CARD

high-impact polystyrene," Fountas remarks, "but some companies that make many terminals probably will. People are looking at it with great interest."

In the packaging arena, engineering themoplastics are still in their infancy. According to Society of the Plastics Industry estimates, just 2 million lb, or about 0.2% of entire U.S. engineering plastics consumption, went into packaging in 1984. But producers see trends emerging, in the consumer, processor, and retailer areas, that should greatly increase demand in coming years, especially in the food segment.

Demographic trends toward smaller and two-worker households are expected to increase the need for convenience in the form of such products as single-serving packages and what the industry calls "dual-ovenable" packages—containers that can be taken from freezer or cupboard, heated in either a conventional or microwave oven, and brought to the table. At the same time, processors and retailers are looking for better barrier properties in packaging plastics, so that more food products can be shipped and stored without refrigeration.

Those converging trends are expected to change the mix of materials used in making food packaging. "Ovenable trays now are mostly of the polyester variety. They are suitable for uses now, but mostly for frozen products," notes Du Pont barrier resin product manager Eidman. "With the trend to shelf-stable products, there must be an improvement in barrier characteristics. So polyester may still be involved in future packaging, but probably only as one layer."

Despite engineering plastics' small presence in packaging today, Du Pont expects substantial growth. The company estimates that about 17% of revenues to producers of packaging materials is accounted for by plastics today, Eidman says. By the end of the century, he says, some 42% of that total will come from plastics. "Of that," he says, "the growth will be primarily in barrier-type structures."

"We're getting out of the embryonic stage into a stage of rapid growth," he predicts. □

Computer Applications in the Polymer Laboratory

Computer Applications in the Polymer Laboratory

New!

Theodore Provder, *Editor*
Glidden Coatings and Resins

Reports on the impact the technological revolution is having on the research worker in polymer chemistry. Reviews the impact of computer technology in the polymer laboratory, and speculates on future trends in task automation. Concentrates on three important areas: Laboratory information generation, management, and analysis tools; instrument automation for polymer characterization; and polymerization cure process modeling and control. Helps bridge the gap between technical and office tools for all scientists and technologists working in the field of polymer research.

CONTENTS
Laboratory Automation: A New Perspective • Economic Considerations of LIMS • Applications of Computer Data Base Management • Advances in Scientific Software Packages • Computer-Assisted Polymer Design • Silicone Acrylate Copolymers • Constrained Mixture-Design Formulations • Analysis of Isochronal Mechanical Relaxation Scans • Automated Rheology Laboratory: Part I • Automated Rheology Laboratory: Part II • Automated Analyses for the Tensile Tester • Data Collection for a Size-Exclusion Liquid Chromatograph • X-ray Pole Figure Studies of Polymers • Computers and the Optical Microscope • Simulation Activities in a R&D Laboratory for Coatings • Flexible Control of Laboratory Polymer Reactors • Control of a Polystyrene Reactor • The Modeling of Polymerization Kinetics • Mathematical Modeling of Emulsion Polymerization Reactors • Kinetics Analysis of Consecutive Reactions • Optimization of Bake Conditions for Thermoset Coatings • An Anhydride-Cured Epoxy Polymerization • Investigation of Self-Condensation of 2,4-Dimethyol-0-cresol

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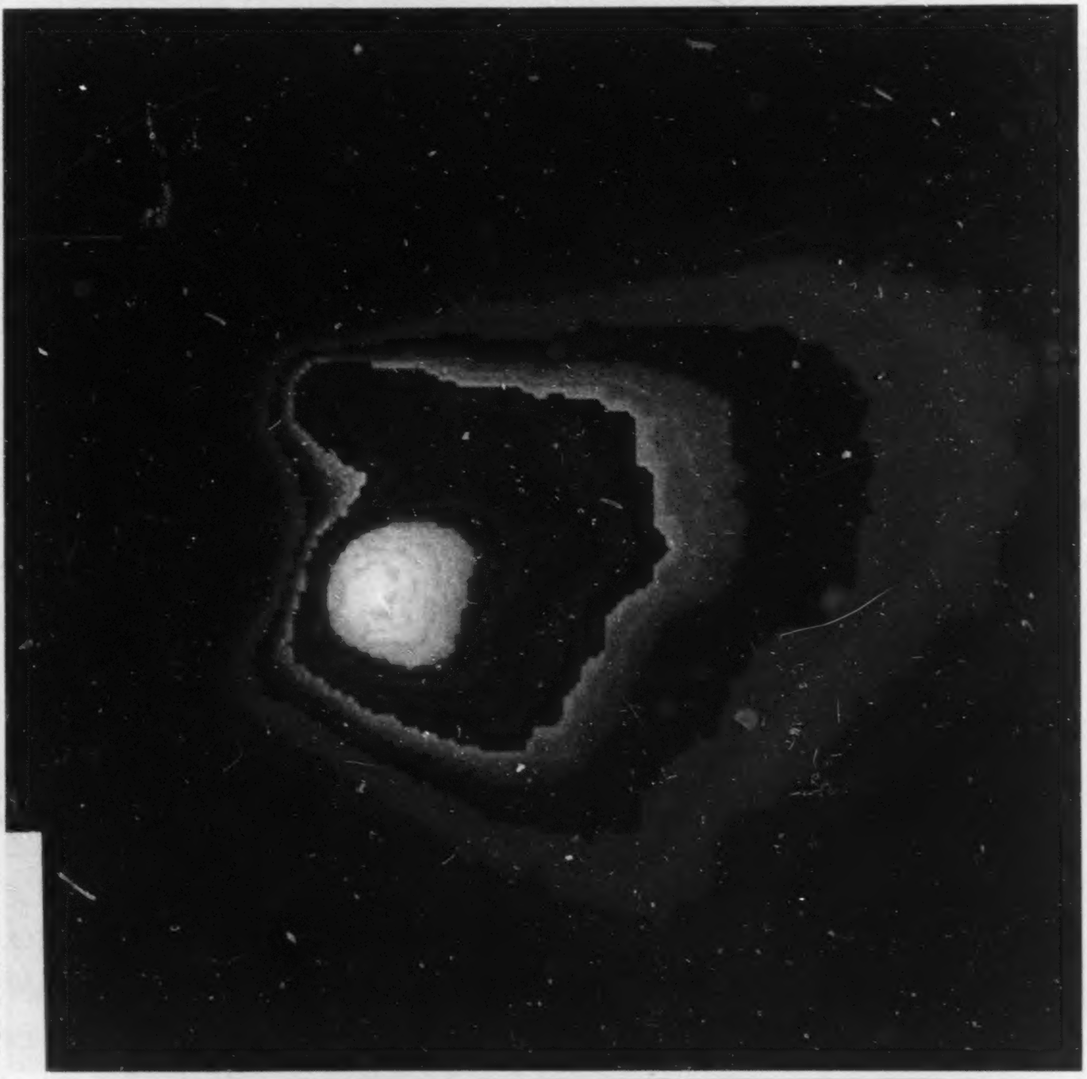
AUGUST 25, 1986

CHEMICAL & ENGINEERING

NEWS



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COMET HALLEY

International effort pays off in bonanza of new findings Page 7

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CHEMICAL & ENGINEERING NEWS

AUGUST 25, 1986

News of the Week

- **ICI buys Glidden, creating world's largest paint firm; increases British company's presence in the North American marketplace. Page 4**
- **Superfund was voted much needed $48 million from Congress; emergency funds would keep cleanup program going through September. Page 5**
- **Office of Technology Assessment gives qualified endorsement of ocean incineration of hazardous wastes. Page 5**
- **Scientists file brief in Supreme court urging it to reject creationism law in Louisiana. Page 5**
- **President Reagan draws sharp criticism as he announces plans for new shuttle, other space programs. Page 6**
- **EPA program seeks to reduce health risks from radon and educate the public about existing hazards. Page 6**

Cover: Two neighboring dust jets shooting out from Halley's dark nucleus appear in arbitrarily chosen colors representing different brightness levels. This Giotto photo shows a small part of the nucleus as an irregular brown area, top left. Copyright, Max Planck Institute of Aeronomy

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Business

Pharmaceutical companies' earnings rose substantially in the second quarter through higher sales, favorable foreign exchange rates. **Page 15**

Government

Proposed OSHA regulation offers labs much flexibility regarding worker exposure to hazardous chemicals. **Page 17**

Science Policy

Importance of science and technology to foreign relations is underscored by work of federal interagency committee. **Page 19**

Education

Plenary sessions on science anxiety, teaching chemistry to kids, and microscale labs highlight chemical education conference. **Page 22**

Technology

Methanol's dual role in chemicals and fuel enhances its importance, spurring development of new processes and plants. **Page 24**

Seawater-damaged tapes from space shuttle *Challenger* restored by IBM scientists using acid washes in delicate procedure. **Page 30**

ACS News

Petition candidate makes four to vie for director for Region IV; ACS criticizes House committee's decision to cut Department of Energy's budget request for chemical sciences program. **Page 32**

News Focus

Five space probes sent past Halley's comet, together with Earth-based observations, reveal a wealth of new information and surprises. Page 7

Drug Company Earnings Rise Again

A combination of higher sales volumes, favorable foreign exchange rates, and other factors helped major U.S. pharmaceutical companies increase their net income an average of 16% in the second quarter of 1986. A group of 16 firms also recorded a composite sales gain of 22% in the quarter, compared to the equivalent period a year earlier. However, the group's average profit margin (after-tax earnings as a percentage of sales) dropped to 10.8% from 11.4% a year before.

The continued weakening of the U.S. dollar against other currencies fattened the bottom line in most cases. At Squibb, for example, currency fluctuations had a net effect of adding $12.7 million to income in the second quarter after contributing to a $9.2 million subtraction in the first quarter of the year. Becton-Dickinson estimates that its second-quarter sales were raised $18 million and net income $6 million by the effects of exchange rates.

SmithKline Beckman and Bristol-Myers both recorded unusual charges in the quarter related to product-tampering scares. At SmithKline, for instance, reintroduction of Contac cold medicine, which was withdrawn from the market in March, cut pretax earnings $10 million. That charge followed first-quarter charges totaling $57.8 million reflecting product withdrawal costs and an early retirement program.

In late June, Bristol-Myers withdrew all its nonprescription capsules from sale as a result of tampering with Excedrin capsules. According to chairman Richard L. Gelb, the withdrawal cost the company $38 million before taxes and $19 million after taxes.

Becton-Dickinson increased net income 40% on a sales gain of 31%, compared with second-quarter 1985. Product sales rose 27% to nearly $185 million, including $18 million of sales from Desert Medical Products, acquired May 30. Nonhealth care product sales declined 2% to $38.9 million, largely because of the divestiture of the company's Digitran division.

Eli Lilly earnings rose 14% on a 16% sales increase in the second quarter. "All business segments contributed to the record sales growth for the second quarter," says chairman Richard D. Wood. The company cites U.S. sales of oral antibiotics, injectable antibiotics, and global sales of genetically engineered insulin in particular. Sales by the company's Hybritech subsidiary increased 40% to $11.3 million. During the first half of the year, Hybritech sales grew 56% to $22.6 million.

For Upjohn, net income leaped 24% on a 9% increase in sales. "Earnings for the quarter were excellent because of the continuing strong performances of our major pharmaceutical products," comments chairman R. T. Parfet Jr. "Gross margins benefited from a favorable product mix as cost of goods sold decreased as a per cent of sales compared to the year-earlier quarter." Sales of human health care products rose 19% in the quarter, offsetting a 12% slump in agricultural sales.

David Webber, New York

Pharmaceutical earnings increased 16% in second quarter

	SECOND-QUARTER 1986						FIRST-HALF 1986					
	Sales ($ millions)	Earnings[a] ($ millions)	Change from 1985 Sales	Change from 1985 Earnings	Profit margin[b] 1986	Profit margin[b] 1985	Sales ($ millions)	Earnings[a] ($ millions)	Change from 1985 Sales	Change from 1985 Earnings	Profit margin[b] 1986	Profit margin[b] 1985
Abbott Laboratories	$ 938.0	$133.6	13%	16%	14.2%	13.9%	$1583.2	$257.[illegible]	−12%	18%	16.2%	12.0%
American Home Products	1198.0	183.3	8	9	15.1	15.0	2462.7	378.2	6	9	15.4	15.0
Avon Products	711.9	38.9	22	22	5.5	5.4	1320.4	54.6	18	20	4.1	4.1
Baxter Travenol	1422.0	51.0	178	19	3.6	8.4	2789.0	100.0	173	22	3.6	8.0
Becton-Dickinson	377.4	31.7	31	40	8.4	7.9	656.5	62.9	14	41	9.6	7.8
Bristol-Myers	1171.8	138.3	9	11	11.8	11.5	2366.3	282.9	9	15	12.0	11.4
Eli Lilly	879.3	125.7	16	14	14.3	14.5	1867.6	298.3	12	10	16.0	16.3
Merck	1005.0	173.2	15	26	17.2	15.7	1926.1	331.0	11	23	17.2	15.5
Pfizer	1117.9	156.1	12	14	14.0	13.7	2150.0	325.0	10	14	15.1	14.6
A. H. Robins	172.6	9.9	5	−29	5.7	8.5	364.1	33.1	10	−7	9.1	10.7
Schering-Plough	585.3	71.8	13	30	12.3	10.6	1198.0	143.6	14	26	12.0	10.9
SmithKline Beckman	882.6	123.4	15	2	14.0	15.8	1745.7	268.7	13	6	15.4	16.4
Squibb	584.8	67.7	23	29	11.6	11.0	1143.7	122.7	23	30	10.7	10.2
Sterling Drug	488.9	36.6	14	10	7.5	7.7	909.1	71.9	11	10	7.9	7.9
Upjohn	594.2	64.7	9	24	10.9	9.6	1131.6	127.7	11	19	11.3	10.5
Warner-Lambert	761.2	72.6	−6	9	9.5	8.2	1508.2	137.7	−6	9	9.1	7.9

a Excludes significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales.

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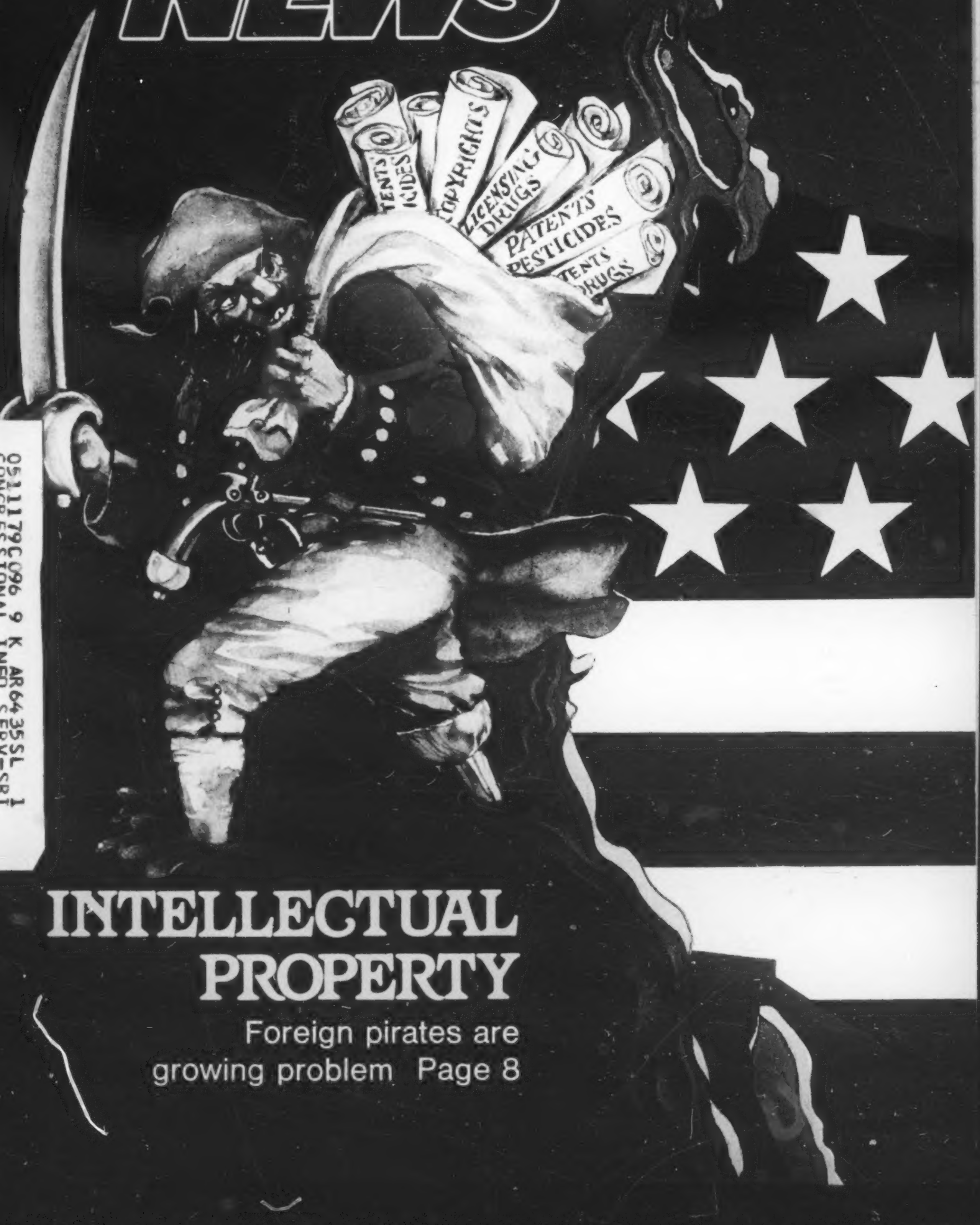
SEPTEMBER 1, 1986

CHEMICAL & ENGINEERING

NEWS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INTELLECTUAL PROPERTY

Foreign pirates are growing problem Page 8

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ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

SEPTEMBER 1, 1986

News of the Week

- **Scanning tunneling microscope is now used to image surface atoms and the individual electronic bonds that hold them in place.** Page 4
- **California likely to alter unitary tax; pending legislation would give multinational corporations alternative method of calculating state taxes.** Page 5
- **Toxic gases released from lake bottom by natural disturbance kill at least 1500 and injure hundreds near Lake Nios in Cameroon.** Page 5
- **Federal district court blocks payments of agent orange settlement benefits to Vietnam war veterans.** Page 6
- **Lehigh University purchase of labs from Bethlehem Steel will double the size of its campus.** Page 6

Business

Biotechnology firms' revenues rose substantially in second-quarter 1986 because of higher product sales and new research contracts. **Page 17**

Government

New chemical spill test facility run by Department of Energy conducts first tests; site is available to private industry. **Page 20**

Office of Management & Budget changes regulatory review procedures, and opts for more open process. **Page 21**

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Research on anticancer activity of mitomycins reveals information on metabolic activation and reactions of metabolites with DNA. **Page 26**

Physicist Charles R. Gossett has developed a method to detect the presence of light elements near the surface of a solid. **Page 27**

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Use of coal-water mixture in fluidized-bed combustors scheduled for tests by Department of Energy and two British organizations. **Page 28**

Books

"High Tech and Toxics: A Guide for Local Communities" tackles the emotional issue of environmental pollution. **Page 29**

News Focus

Increased piracy by overseas companies of U.S. agrochemical and drug firms' intellectual property has companies turning to Washington for stronger protection. Page 8

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Biotechnology Firms Record Substantial Revenue Increases

Product sales are on the rise as are costs of conducting proprietary research; equity and debt offerings help firms strengthen cash balances

David Webber, C&EN New York

Thanks to either higher product sales or new and bigger collaborative research agreements, most biotechnology firms' total revenues rose substantially in second-quarter 1986. At the same time, some companies—Genentech, Applied Biosystems, and Centocor, in particular—reported net income that made them highly profitable by most measures, whereas other firms reduced net earnings or widened losses as they boosted spending on proprietary research and development.

The second three months of the year also featured a large number of stock offerings—both initial and secondary—that bolstered assets around the industry. As a result of the initial stock offerings, several companies are now publicly reporting their financial performance for the first time.

Calgene, Davis, Calif., for example, went public July 8 with a stock offering that netted the company $29.3 million from the sale of 2.25 million shares of common stock. During the second quarter (the company's fiscal third quarter), Calgene forged new relationships with Procter & Gamble and Philip Morris and expanded its contract R&D agreements with Campbell Soup and Rhône-Poulenc Agrochimie.

In addition, in May Calgene acquired Agro Ingredients, a marketer of specialty plant oils and ingredients to industrial users and food processors. Also during the second quarter, Calgene signed an agreement with Ciba-Geigy under which Calgene will develop disease-resistant crop plants.

As a result of the new research contracts, Calgene's product development revenues jumped 217% to $1.1 million. Sales, nonexistent the year before, totaled $882,000, essentially the result of the Agro Ingredients acquisition. Overall, Calgene's total revenues ballooned 465% to $2.1 million, while the company's net loss narrowed to $329,000 from a deficit of $1.1 million in last year's second quarter.

Genetics Institute, Cambridge, Mass., went public in May with an

Revenues rose sharply in the second quarter

	SECOND-QUARTER 1986[a]						FIRST-HALF 1986[a]					
	Revenues[b] ($ millions)	Earnings[c] ($ millions)	Change from 1985		Profit margin[d]		Revenues[b] ($ millions)	Earnings[c] ($ millions)	Change from 1985		Profit margin[d]	
			Revenues	Earnings	1986	1985			Revenues	Earnings	1986	1985
Amgen	$ 7.700	$0.474	133%	nm	6.2%	def	$14.569	$ 0.679	119%	nm	4.7%	def
Applied Biosystems	16.775	2.770	41	25%	16.5	18.6%	31.991	5.424	43	31%	17.0	18.6
Biogen	2.849	−6.677	−57	def	def	def	6.671	−12.944	−42	def	def	def
BioTechnica International	1.729	−0.900	36	def	def	def	3.602	−2.022	44	def	def	def
Calgene	2.101	−0.329	465	def	def	def	3.310	−0.634	482	def	def	def
California Biotechnology	3.867	0.066	64	38	1.7	2.0	7.111	−0.083	64	def	def	def
Centocor	8.690	1.912	63	138	22.0	15.1	15.991	3.514	63	171	22.0	13.2
Cetus	12.537	0.015	16	−97	0.1	4.9	27.539	0.375	18	−50	1.4	3.2
Damon Biotech	1.284	−2.622	39	def	def	def	2.857	−7.980	6	def	def	def
Genentech	32.649	2.823	52	156	8.6	5.1	61.691	4.576	48	152	7.4	4.4
Genetics Institute	4.878	−1.038	29	def	def	def	9.295	−1.975	30	def	def	def
Immunex	2.175	−0.181	211	def	def	def	3.483	−1.029	166	def	def	def
Molecular Genetics	1.584	−1.263	−17	def	def	def	4.346	−1.250	2	def	def	def
Monoclonal Antibodies	2.444	0.139	36	nm	5.7	def	4.996	0.320	51	nm	6.4	def
Ribi ImmunoChem	0.413	−0.081	144	def	def	def	0.808	−0.116	145	def	def	def
Synergen	2.001	0.064	15	−59	3.2	9.1	4.232	0.365	23	−10	8.6	11.8

a For three-month and six-month periods ending closest to June 30. b Includes sales, contract research, royalty, and interest revenues. c Excludes extraordinary credits and nonrecurring items. d After-tax income as a percentage of sales. def = deficit. nm = not meaningful.

Product sales account for greater revenues

	Product sales ($ millions)	% change from 1985	Sales as % of total revenues	
			1986	1985
Amgen	$ 0.237	11%	3%	6%
Applied Biosystems	14.621	41	87	88
Biogen	0	nm	nm	nm
BioTechnica International	0	nm	nm	nm
Calgene	0.882	nm	42	nm
California Biotechnology	0	nm	nm	nm
Centocor	2.652	55	31	32
Cetus	0.554	98	4	3
Damon Biotech	0	nm	nm	nm
Genentech	9.461	nm	29	nm
Genetics Institute	0	nm	nm	nm
Immunex	0	nm	nm	nm
Molecular Genetics	0.103	−60	7	13
Monoclonal Antibodies[a]	na	nm	nm	nm
Ribi ImmunoChem	0.128	35	31	56
Synergen	0	nm	nm	nm

[a] Not available. In quarter ending March 31, 1986, product sales accounted for 87% of total revenues. na = not available. nm = not meaningful.

initial offering of 2.88 million shares that raised more than $85 million. Like Calgene, the company arranged several new product development agreements and increased certain existing collaborative arrangements, says Gabriel Schmergel, president and chief executive officer. Those achievements helped raise revenue 29% to $4.9 million in the quarter.

At the same time, Genetics Institute's net loss for the quarter widened to $1.0 million from $769,000 in the year-earlier period. The reason is an increase in operating expenses associated with proprietary research and product development. Operating expenses jumped nearly 20% in the quarter.

"We are in the process of expanding our proprietary product development programs, which naturally will increase our operating expenses without providing related revenue coverage," Schmergel explains. "We are committed to allocating a prudent level of equity capital to the development of proprietary products with attractive risk/reward profiles."

Among other newly public companies reporting financial performance for the first time, losses tended to widen as the firms, their bank balances built up through the stock market, added staff members and shifted activities to proprietary research. Liposome, Princeton, N.J., which made an initial offering on July 23, reported that it lost $1.1 million on revenues of $632,000 ($457,000 in R&D fees, the rest in interest income). The quarterly loss increased $213,000 over second-quarter 1985. Cytogen, Princeton, N.J., lost $1.0 million on $569,000 in revenues. The loss was $52,000 greater than in the comparable 1985 period. T Cell Sciences, Cambridge, Mass., lost $1.7 million in the year ending April 30, 1986. That represented an extra $670,000 in deficit for the company, which went public in May.

Sales of genetic engineering products achieved their greatest prominence in the second quarter at Genentech. The industry leader raised its overall revenues 52% to more than $32.6 million in the quarter. The most important single element in that sharp increase was the $9.5 million in revenues from sales of Protropin human growth hormone, first commercialized last fall. Product sales accounted for 29% of total revenues in the second quarter. As a result, net income jumped 156% to $2.8 million. Over the first six months of the year, Genentech total revenues climbed 48% to $61.7 million, and earnings rose 152% to $4.6 million.

Another firm with a big rise in biotechnology product sales was Centocor, Malvern, Pa. Centocor raised total revenues 63% to $8.7 million, helped considerably by product sales of $2.7 million, up 55% from the year-earlier quarter. As a result, product sales accounted for 31% of total revenues, compared with 32% a year before and 34% in first-quarter 1986.

At Immunex, Seattle, second-quarter revenues leaped 211% to nearly $2.2 million. At the same time, the company reduced its net loss to $181,000, compared with a $1.2 million deficit a year before. The chief reasons for the company's increase in revenues were increased research activities and the passing of research milestones in Immunex's collaboration with Behringwerke of West Germany, and its joint venture with Eastman Kodak to develop human immunological therapeutic products, the company says.

Research revenues in the quarter increased 282% to $1.8 million. Interest income, generated from an asset base bolstered by the company's March stock offering, nearly doubled to $422,000.

California Biotechnology also benefited from a sharp increase in R&D contract revenues and interest income. Research revenues jumped 34% to $2.2 million in the second quarter, and investment income increased 136% to $1.6 million. As a result, total revenues rose 64% to $3.9 million, but net income was small.

The company concluded two important commercial agreements during the second quarter, according to chairman William G. Baker Jr. Cal Bio is researching for Hoffmann-La Roche the use of the biotechnology company's nasal delivery technology with antiobesity and growth hormone products. In addition, Cal Bio signed a licensing agreement with Byk Gulden, a West German pharmaceutical company, covering European marketing rights for Cal Bio's lung surfactant, a product under development to treat infant respiratory distress syndrome. □

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SEPTEMBER 8, 1986

CHEMICAL & ENGINEERING

NEWS

Allied-Signal's Mary Good analyzes challenges to the chemical profession
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CHLOR-ALKALIES

Capacity cuts are helping firm up prices

A Key Chemicals Review
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CHEMICAL & ENGINEERING
NEWS
SEPTEMBER 8, 1986

News of the Week

- **Plastic resins production and shipments rose in first half of year, according to latest figures.** Page 4
- **New vaccine has been developed against simian acquired immune deficiency syndrome; provides hope for AIDS vaccine.** Page 5
- **An Environmental Defense Fund report aims at helping state and federal government agencies reduce the amount of hazardous waste produced.** Page 5
- **Genetic engineering critic Jeremy Rifkin seeks court injunction against DOD biological defense research experiments.** Page 5
- **Use of 2,4-D herbicide linked to increased risk of rare form of cancer, according to study of Kansas farmers who use the pesticide.** Page 6

Cover: Huge electrolyzers dominate PPG Industries' chlorine-caustic soda plant at Lake Charles, La., where washdown is a regular practice to ensure a clean environment and safe footing

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Business

Combination of earlier plant shutdowns to reduce capacity and recent rise in demand has led to firm price increases for makers of chlorine, caustic soda, and soda ash. **Page 17**

Government

Congress is back in session and faces a full slate of unresolved business putting finishing touches on the tax reform bill and providing fiscal 1987 funding for federal departments and agencies. **Page 28**

Technology

Environmental pollution by metals is a growing concern in the industrialized world; progress has been made in arresting metals pollution, but awareness of the problem must be increased. **Page 37**

ACS News

ACS announces 1987 national award winners; society comments on Senate version of tax reform legislation, and supports keeping university research facilities eligible for tax-exempt bond financing. **Page 47**

News Focus

Mary Good, Allied-Signal research executive and president-elect of ACS, discusses the threats that afflict the chemical profession and the remedial changes that are needed. Page 7

PLASTIC RESINS:
Output increased 5.5% in first half

Both production and shipments of plastic resins rose in the first half of this year, according to the latest figures released by the Society of the Plastic Industry's Committee on Resin Statistics. Although growth in no way matches the golden years of plastics, the figures do pretty much match average annual growth in the industry for the past five years.

The data, as compiled by the accounting firm of Ernst & Whinney, show output of resins in the first six months totaling almost 21.8 billion lb, up 5.5% from the same period in 1986. Sales and captive use of all resins totaled almost 21.5 billion lb, an increase of 4.9% from the first six months last year. The disparity between the production figures and the shipments numbers indicates that there was some inventory building in the first half.

Demand for thermosets moved up faster than that for thermoplastics, but thermoplastics' output rose faster than thermosets'. According to SPI, thermosetting resin shipments in the first six months totaled 2.95 billion lb, up 5.1% from the 1985 period. Sales and captive use of thermoplastics in the same period increased 4.8% to 18.5 billion lb. Production of thermoplastic resins rose 5.5% to 18.8 billion lb, whereas output of thermosets climbed 5.1% to almost 2.95 billion lb.

The growth leader among the thermosets in both production and shipments was urea resin, with sales and captive use up 7.2% to about 650 million lb and production up 6.8% to 653 million lb. This was closely followed by phenolic and other tar acid resins, whose shipments climbed 6.8% to 1.37 billion lb and whose production increased 6.4% to 1.36 billion lb.

Among the major thermoplastic resins, some showed strong growth. Shipments of polyvinyl chloride increased 10% to 3.63 billion lb; production of the polymer rose 5.0% to 3.56 billion lb. Polystyrene shipments increased 8.1% to 2.21 billion lb and output of this plastic rose 5.5% to 2.14 billion lb. High-density polyethylene sales and captive use climbed 7.3% to 3.35 billion lb; production increased 6.7% to 3.49 billion lb. And demand for polypropylene rose 6.9% to 2.77 billion lb; production of this resin jumped 12.8% to 2.83 billion lb.

The two major thermoplastics performing poorly were low-density polyethylene and acrylonitrile-butadiene-styrene. Sales and captive use of LDPE in the first six months declined 2.6% from the same period a year ago to 4.21 billion lb. Production of LDPE totaled 4.41 billion lb, up just 1.8% from the same period in 1985. Demand for ABS slipped 1.3% to 522 million lb; output of this plastic increased a scant 1.0% to 540 million lb.

The trade surplus in volume remains strong for plastics. Total plastics exports in the first six months amounted to 1.89 billion lb, a gain of 13.1% over the same period last year. Imports totaled 679 million lb, down 1.6% from the first half of the year before. Thus, the poundage surplus was almost 1.22 billion lb, up 23.4% from the first six months of 1985.

Thermoplastics are responsible for the increased trade surplus, with exports up 14.6% in the first six months to 1.80 billion lb and imports down 2.9% to 632 million lb. The volume surplus thus amounted to 1.17 billion lb, an increase of 27.1% from the same period last year.

Thermosets' foreign trade is much smaller than thermoplastics', and their surplus decreased in the first six months. Exports of thermosets amounted to 96 million lb in the first half, down 9.4% from the same period in 1985, and imports were 47 million lb, up 20.5%. As a result, their trade surplus shrank 26.9% to 49 million lb.

Shipments of most major plastics moved up in first six months

Millions of lb	First half 1986	1985	% change
THERMOSETS	2,951	2,808	5.1%
Epoxy	191	190	0.7
Polyester	644	634	1.7
Urea	650	606	7.2
Melamine	97	97	0.0
Phenolic	1,369	1,282	6.8
THERMOPLASTICS	18,518	17,667	4.8%
Low-density polyethylene	4,208	4,322	−2.6
High-density polyethylene	3,354	3,127	7.3
Polypropylene	2,775	2,594	6.9
Acrylonitrile-butadiene-styrene	522	529	−1.3
Polystyrene	2,208	2,043	8.1
Polyvinyl chloride	3,630	3,299	10.0
Other	1,822	1,753	4.0
TOTAL	21,470	20,475	4.9%

Source: SPI Committee on Resins Statistics as compiled by Ernst & Whinney

Preliminary figures from SPI for July for some individual resins show demand for polystyrene jumping 15.8% to 369 million lb from July 1985. Polypropylene use is up 14.6% to 478 million lb, low-density polyethylene has increased 10.4% to 806 million lb, and polyvinyl chloride rose 5.5% to 575 million lb. Demand has fallen only for high-density polyethylene and acrylonitrile-butadiene-styrene, according to the preliminary estimates, with HDPE slipping 0.3% to 588 million lb and ABS dropping 4.7% to 78.4 million lb. □

Chlor-Alkalies Profit From Plant Shutdowns

Capacity rationalization coupled with higher demand shores recent price increases for producers of chlorine, caustic soda, and soda ash

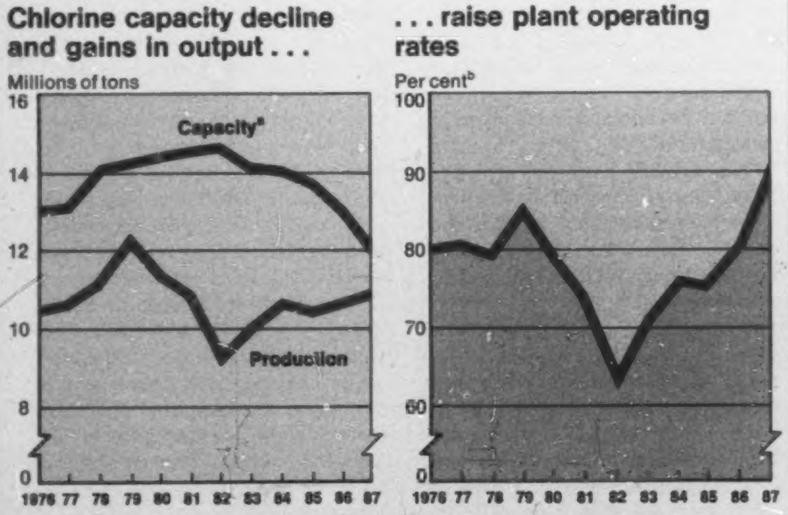
Bruce F. Greek, C&EN Houston

Technological developments aimed at improving efficiency in producing chlorine, caustic soda, and soda ash as well as capacity rationalization and improved demand for these chlor-alkalies are helping to firm prices and to improve profitability for the chlor-alkali industry. If the modest demand growth follows forecasts, sizable expansions of capacity could be needed later on.

Because oversupply had led to lower selling prices and reduced profitability for more than a decade, capacity cutbacks in chlor-alkalies had long been anticipated. In the late 1970s when a return to traditional high operating rates appeared to be certain, capital was authorized for capacity additions, and the stage was set for overcapacity to grow again as the 1980s began. Consequently, the new capacity had to be utilized because of the investment. New process developments, however, occurred about the same time—particularly membrane technology for brine electrolysis cells. Those developments began to make older chlorine cells obsolete.

Key Chemicals

Similar events affected soda ash, although the high cost of pollution control has had the biggest impact. Synthetic soda ash was doomed by costly-to-handle waste streams and by development of natural sources that can be machine-mined at low cost. The end of U.S. manufacture of synthetic soda ash this year has had the same effect that shutdowns of chlorine plants have had: higher operating rates for remaining soda ash plants and higher selling prices.



a Average at beginning and end of year; includes all operable capacity at nameplate values. b Based on averaged capacity. **Sources:** Chlorine Institute, Department of Commerce, C&EN estimates

The outlooks for these three chlor-alkalies differ. U.S. natural soda ash will remain less dependent on energy costs than will chlorine and caustic soda. It will have much lower pollution control costs than will the continuing synthetic production in European and other countries. A continuing rise in U.S. exports of soda ash is forecast as pollution controls become more stringent in other parts of the world. Returns from sales of soda ash do not yet justify the large investment needed to expand capacity at producing points in Wyoming. Because of growth in exports, a tight supply of soda ash before the end of the 1980s is forecast by some observers despite a continuing decline in its major market, glass making.

Chlorine and caustic soda consumption could again be buffeted by competition from new capacity built in the Middle East, where energy costs are low. However, as no major additions to capacity by the end of the 1980s in the Middle East have been announced, that situation is unlikely to develop until the next decade. Recently completed capacity in the Middle East has been absorbed into world markets with minor impact on U.S. producers. With U.S. capacity operating above 90% of nameplate and with demand expected to rise modestly throughout the rest of this decade, supplies of the two chlor-alkalies also could tighten.

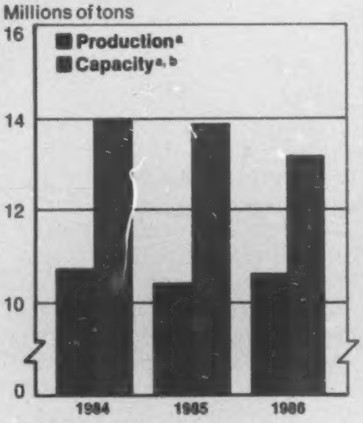
For some details of the near-term outlook for these chlor-alkalies, please see the following pages.

Cl_2

Chlorine

- ***Output up slightly***
- ***Capacity declining***
- ***Prices higher***

PRODUCTION/CAPACITY



a All sources. b First quarter.

MAJOR PRODUCERS

Diamond Shamrock, Dow Chemical, Occidental, Olin, PPG Industries, Vulcan Materials

HOW MADE

Electrolysis of NaCl brine; recovery from HCl; coproduct of metals manufacture, electrolysis of KCl brine

MAJOR DERIVATIVES (U.S.)

Ethylene dichloride 20%, other C_2 derivatives 10%

MAJOR END USES (U.S.)

Organic chemicals and plastics 65%, pulp and paper manufacturing 15%

FOREIGN TRADE

Exports—holding at 50,000 tons, imports—rising to 300,000 tons

PRICES

List price $195 per ton on Gulf Coast; actual prices below list

Chlorine production is forecast to rise about 2% this year. Other good news for producers are recent shutdowns of capacity, which have raised operating rates of remaining on-stream capacity. Also, rising operating rates are allowing the off-list price increases generally to hold.

Total chlorine output in 1986, forecast to reach 10.6 million tons, will be up from last year's production of slightly more than 10.4 million tons, according to the Chlorine Institute. Actual reported production during the early part of 1986 has been below an annualized rate of 10.6 million tons, but sources expect that the traditional up and down swings that occur later in the year will differ from the normal pattern, resulting in the higher total.

Significant capacity changes in 1986 are behind the large increase in operating rates expected this year and in 1987. Two of the recent shutdowns were at major plants. Dow Chemical took 450,000 tons of annual nameplate capacity off the list in July, and Du Pont shuttered about 550,000 tons of capacity at the end of July.

Those large capacity reductions follow shutdowns by several companies in 1985 totaling more than 700,000 annual tons, the Chlorine Institute estimates. Early this year, in-place capacity for chlorine totaled about 13.2 million tons per year. About 900,000 tons of that capacity was closed down, and much of the operating capacity ran at reduced rates.

With another 1 million tons of capacity now down, the total operating capacity is currently 11.3 million tons per year. If production totals 10.6 million tons for the year, and the average operable capacity falls to 12.8 million tons, the operating rate will be almost 83%. Excluding the nonoperating capacity for the entire year, the average rate would be 89%.

Even with the shuttering of a substantial amount of chlorine capacity over the past 18 months, supplies are more than adequate. Growth in demand for chlorine this year is 2%, which matches the rate forecast for the rest of the 1980s. If demand continues to grow at the same rate over the next few years, additional capacity expansions beyond those now under way will be needed. The largest such expansion in progress is a joint venture of Du Pont and Olin at Niagara Falls, N.Y., which would add more than 200,000 tons per year.

There is little change in the use pattern for chlorine. Most major applications are following predictions of no growth to less than 5% annual growth. The largest single use is ethylene dichloride, which eventually becomes various fabricated products of polyvinyl chloride, and that use is having a good year because lower interest rates are spurring housing and auto production. The improvement in the PVC business this year is triggering much of chlorine's production growth. Markets for the other major chlorinated organic chemicals and derivatives are growing slowly, except that for propylene glycol, which is growing well because of demand for polyurethanes.

Bleaching wood pulp is the second largest market for chlorine. Growth in this use also continues to be modest, probably less than 1% annually. Threatening chlorine growth in pulping uses are pollution control concerns, which have brought about efforts to substitute oxygen for chlorine. But progress has been slow, and chlorine will likely keep this market for some time.

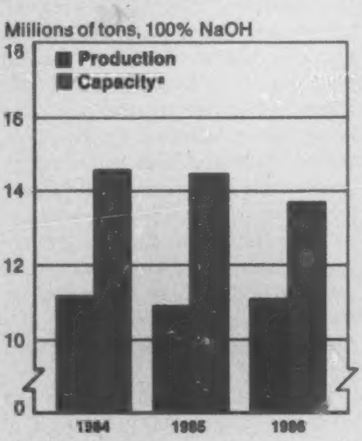
Another major use for chlorine is water treating, which is growing slowly. Concern about forming trihalomethanes as the result of treating water with chlorine has led to proposals for use of other disinfectants such as ozone, hydrogen peroxide, and chloramine, which eventually may cut into this market for chlorine. Other chemical uses of chlorine are relatively small and, although some are having fair growth this year (such as titanium dioxide), the effect on chlorine demand growth is modest.

NaOH

Caustic soda

- ***Production up slightly***
- ***Capacity dropping***
- ***Prices firming***

PRODUCTION/CAPACITY



a First quarter.

MAJOR PRODUCERS

Diamond Shamrock, Dow Chemical, Occidental, Olin, PPG Industries, Vulcan Materials

HOW MADE

Electrolysis of NaCl brine

MAJOR DERIVATIVES (U.S.)

None taking more than 5% of consumption

MAJOR END USES (U.S.)

Chemicals manufacture 50%; pulp and paper manufacturing 20%; soap, detergents, and cleansers manufacture 5%

FOREIGN TRADE

Exports—holding at about 1.1 million tons, imports—rising to about 600,000 tons

PRICES

List price $175 per ton on Gulf Coast; discounting prevalent

Caustic soda output will increase this year because of a rise in chlorine production and will increase about the same amount, according to the stoichiometry. Except for small quantities added to inventories, the additional output will go into caustic's traditional end uses, dominated by chemical manufacture, which takes about half of U.S. consumption. Because chlorine demand now controls the electrolysis operations, plant capacity for caustic is being reduced roughly the same amount as chlorine capacity. Prices for caustic are weaker than chlorine's because actual demand for caustic is weaker than that for chlorine.

Production of caustic this year will amount to more than 11 million tons as 100% NaOH. (Although most caustic is sold as a 50% solution, production is reported as 100% NaOH.) As a result of plant shutdowns, operable capacity as the year began was about 13.7 million tons, down from 14.5 million tons at the beginning of 1985. Operating capacity at the beginning of 1986 was about 1 million tons less, or about 12.7 million tons. The recent shutdowns of the Dow Chemical and Du Pont chlor-alkali units have reduced capacity about 850,000 tons. For the year, then, the average operable nameplate capacity for making caustic will be reduced to 13.2 million tons. Hence, the operating rates for caustic will be 84% of operable capacity and 91% of operating capacity.

The lower operating rates and a possible 20% gain in imports of caustic (to some 600,000 tons in 1986) keep more pressure on selling prices of caustic than on those of chlorine. Consequently, industry sources point out, caustic is carrying less than its share of the cost of producing an electrochemical unit than is chlorine. This situation will prevail as long as imports rise, exports of caustic remain on hold or decline 5 to 15%, and major uses of caustic languish.

The foreign trade situation for caustic is being buffeted by new production, especially in the Middle East. U.S. exports of caustic, about 1.1 million tons in 1986, could fall 50,000 to 100,000 tons; imports could rise the same amount. Such a change of 100,000 to 200,000 tons in the net of export over imports would have to be either added to U.S. consumption of caustic or put into inventory, if output is to rise about 200,000 tons because of the increase in chlorine output.

The change in the U.S. caustic exports-imports balance stems indirectly from the loss to Middle East producers of some markets formerly held by European producers. As a result, European producers now either are exporting to the U.S. or are competing with U.S. exports going to such areas as Australia and the Caribbean. At present, the capacity of the new Middle East plants has been adsorbed.

U.S. consumption of caustic could be stimulated to some degree by relatively lower prices. Some soda ash used in making certain inorganic chemicals might temporarily be displaced by caustic because of the higher prices for soda ash. However, caustic's dominant use to make chemicals means that demand for chemicals controls its consumption. One of the largest uses for caustic is in converting bauxite ore to alumina (which accounts for the use of a large share of exports). Because aluminum output is down and process improvements reduce caustic consumption, this market has sagged. The many other uses for inorganic chemicals are making up in large part for the decline in this market. Production of organic chemicals, particularly aromatic derivatives, requires large quantities of caustic for neutralization of the waste stream. Growth in this area is modest, at about 2% annually.

Nonchemical manufacturing uses—pulp and paper, soap and detergents and cleansers, and petroleum processing—are growing slightly, if at all, this year. Many of these applications are mature and are not expected to grow much in the future.

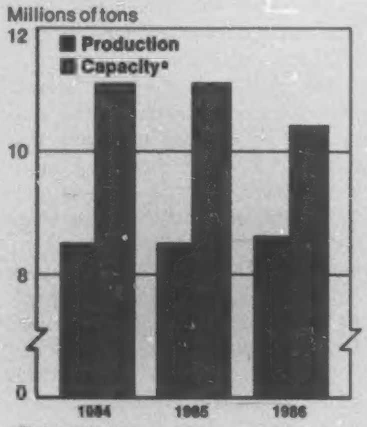
Key Chemicals

Na_2CO_3

Soda ash

- ***Output slowly rising***
- ***Capacity down***
- ***Prices holding***

PRODUCTION/CAPACITY



a First quarter.

MAJOR PRODUCERS

Chesebrough-Pond's, FMC, Henley Group (Allied), Kerr-McGee, Tenneco, Texasgulf

HOW MADE

Recovered from mined trona ore or from brine

MAJOR DERIVATIVES (U.S.)

None accounting for more than 5% of consumption

MAJOR END USES (U.S.)

Glass manufacture 50%; chemicals manufacture 25%; soap, detergents, and cleansers manufacture 10%

FOREIGN TRADE

Exports—rising to 2 million tons, imports—rising to 75,000 tons

PRICES

List price in hopper-car quantities in Wyoming $83 per ton

Exports of soda ash continue to rise and brighten the outlook for an otherwise slow soda ash market this year. Exports of this chemical are expected to top 2 million tons in 1986, which would be close to a quarter of total U.S. output. Domestic uses—headed by glass manufacture—may be up slightly but could be almost level.

Although Allied (now Henley Group) stopped making synthetic soda ash during the first quarter of the year, total production of soda ash in 1986 is forecast to increase over last year's output. The total this year could be 8.7 million tons, especially if export volume grows throughout the year as forecast. However, production probably will be only slightly over 8.6 million tons. Such an increase would be less than 1.5% over 1985 output of more than 8.5 million tons, and that is up only marginally over 1984 production of less than 8.5 million tons.

All soda ash currently is produced either from naturally occurring trona ore mined in the area around Green River, Wyo., or from naturally occurring brines in California. The expected shutdown of the Allied plant in Syracuse, N.Y., which has a capacity of 700,000 tons per year, reduced U.S. nameplate capacity for soda ash to about 10.4 million tons annually.

Effective capacity for soda ash is about 90% of nameplate, or nearly 9.4 million tons per year. If production in 1986 totals 8.7 million tons, the operating capacity will have an average rate of 93% of effective capacity, or 84% of nameplate capacity. Because of the shutdown of the synthetic capacity, these operating rates will be the highest the soda ash industry has had for many years.

Reductions in capacity and strong exports have allowed soda ash producers to raise their list prices $4.00 per ton for carload quantities at the producing plant sites and to maintain the higher price for nearly a year. With prospects for further gains in exports next year and for possibly a small growth in U.S. consumption as well, the higher prices are expected to hold through the rest of this year and later. Actual selling prices, however, have been below list prices for some time.

The growth in U.S. exports of soda ash continues to be in the areas of existing exports, in particular the Pacific Rim nations. Global consumption of soda ash, however, is growing rather rapidly because of growing demand in developing countries for glass containers. Synthetic soda ash capacity worldwide also is expected to continue growing. Nevertheless, total capacity growth lags demand growth, spurring demand for U.S. natural soda ash in many parts of the world. No plans have been announced at this time for possible expansion of U.S. capacity.

Major uses of soda ash are not progressing much this year. Glass of all kinds accounts for half of U.S. consumption of soda ash and its output is slowly declining, taking soda ash consumption with it. The four segments of the glass market have somewhat different outlooks. Glass containers, about two thirds of the total glass market for soda ash, are buffeted by continuing inroads by both plastics (largely polyesters) and aluminum. Their consumption fell last year and is expected to decline further in 1986. Use of flat glass, largely in construction and autos, will be up slightly because of improved sales of houses and autos resulting from lower interest rates. Flat glass accounts for about one sixth of soda ash use in glass. The remaining glass forms—glass fiber and glassware—are forecast to hold about even in demand for soda ash.

All of the other major applications—manufacture of chemicals, pulp and paper, and soaps, detergents, and cleansers—will be flat to slightly up in their consumption of soda ash in 1986. These uses and many small ones will not change total consumption of soda ash from that of last year.

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SEPTEMBER 15, 1986

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Their views and backgrounds
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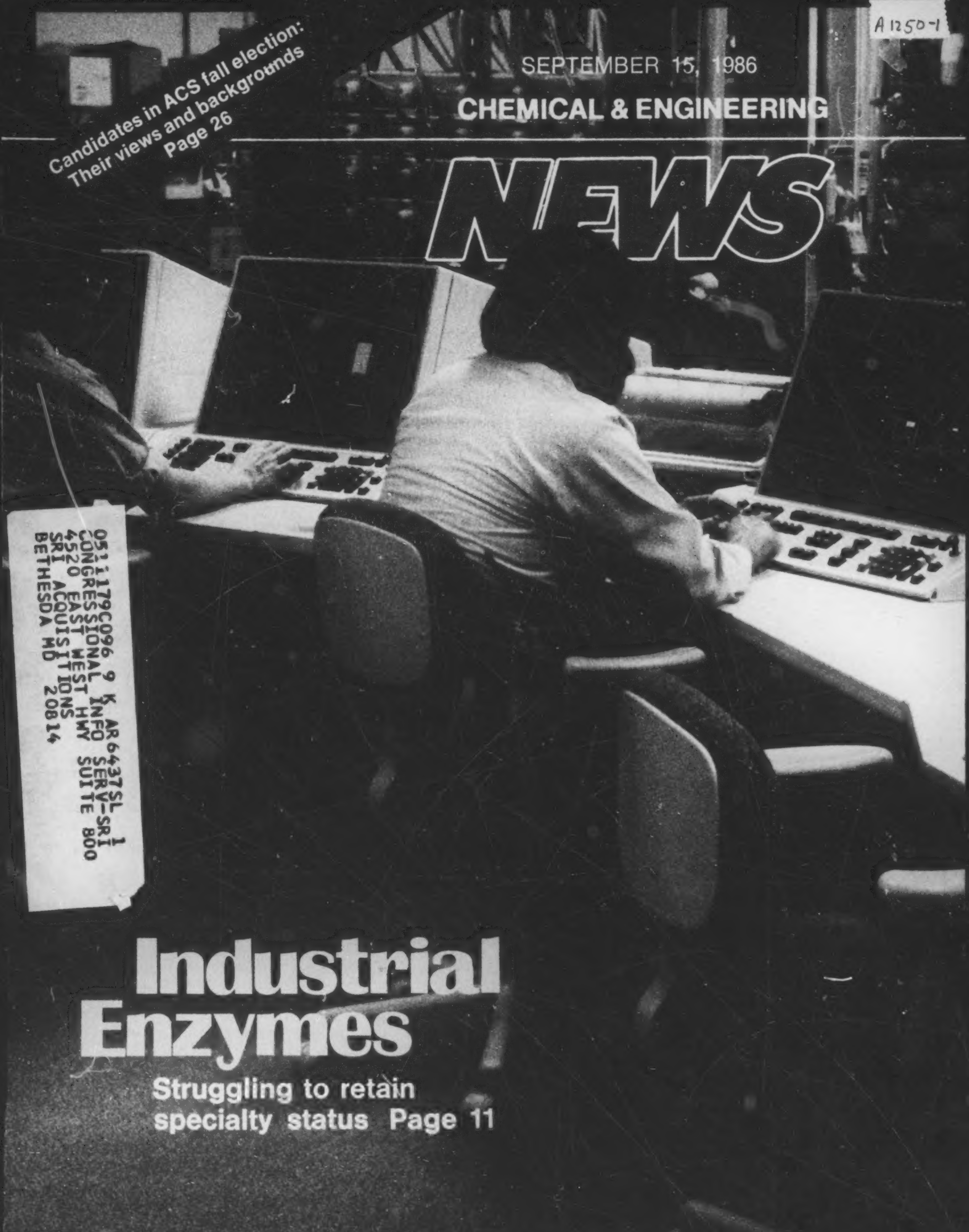

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- The Biotechnology Secretariat, which was recently formed, presents its first technical program. Page 4
- Chernobyl accident generates much interest at Nuclear Chemistry & Technology Division symposium. Page 5
- Lack of manganese in diet may lead to osteoporosis. Page 5
- ACS meeting in Anaheim draws more than 11,000 attendees. Page 5
- ACS meeting-goers on camera in sunny Anaheim. Page 6
- Office of Technology Assessment calls for massive effort to reduce hazardous waste generation. Page 7
- American Fertility Society panel issues ethical guidelines for new reproductive technologies. Page 8
- William R. Graham easily clears science adviser confirmation hearings. Page 8

Cover: CPC International subsidiary Enzyme Bio-Systems Ltd. uses state-of-the-art computer control in producing its line of high-quality industrial enzymes at Beloit, Wis., plant

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Efforts to reach a settlement in the Bhopal case are intensifying as court date approaches. Page 14

International Business

Canadian chemical companies' sales and earnings rose in first half; however, slowing economy has company executives worried. Page 16

Government

Recently released EPA guidelines for risk assessment of chemicals aim at ensuring consistency in agency decisions. Page 18

States have started reforming their tort laws along lines of White House domestic policy council recommendations. Page 20

Science

Inorganic chemist Karl O. Christe generates elemental fluorine by purely chemical means for a historic first. Page 23

Lightweight, high-strength advanced composites find use in new aircraft design at Lockheed-Georgia plant. Page 23

New software for scientific and engineering application provides help with data analysis and experimental design. Page 24

ACS Election

Nominees for 1987 president-elect, director-at-large, and directors for regions II and IV comment on ACS governance. Page 26

Cover Story

Industrial enzymes struggle to overcome commodity status of past few years; although consumption has gone up, the prices of some key enzymes have fallen. Page 11

Industrial Enzymes Battling To Remain Specialties

Consumption has gone up but prices of some key enzymes have fallen as they have suddenly slid into commodity status

Patricia L. Layman, C&EN London

With most segments of the chemical industry fighting to move from commodity to specialty products, the commercial enzymes business is no exception. Perhaps what makes the enzymes business stand out, however, is that it started out as what most people would call "specialty" and in the past five years has tumbled into commodity marketing, a label it is now struggling to overcome.

This, in brief, is the conclusion of London-based consultants L. Hepner & Associates, in a new study, Industrial Enzymes by 1990—Specialities vs. Commodities. An earlier study, which had looked at the industry as it stood in 1980, identified some 16 industrial enzymes, in a market of $300 million. At the time, the consultants predicted that sales would reach $500 million by 1985.

"Our estimates of consumption were right—that has gone up. However, we had assumed constant, level prices or an increase with inflation. And prices for some key enzymes have decreased," concedes Leo Hepner. In fact, the total market for industrial enzymes is now about $400 million. And that takes in an expanded slate of 22 such enzymes, which Hepner and codirector Celia Male have defined as those items with sales of more than $500,000 each.

What has gone wrong with the enzyme business since 1980? The basic problem is that in one of the major markets—converting starches into ethanol, glucose syrups, and the like—enzymes have taken a sudden slide into commodity status, with serious price pressure. In 1980–81, the average price of enzymes was about $12 to produce 1 metric ton of high-fructose syrup, including such "specialty" enzymes as high-temperature amylase, glucoamylase, and glucose isomerase. Now, it is about half that, about $6.00 to $7.00 to produce 1 metric ton.

At the time, says Male, the market was just large enough to support a certain number of producers. But with the spotlight on biotechnology, a number of new producers came in, with not surprising impact on the pricing structure. For example, starch conversion is the major end use for commercial enzymes, accounting for more than 50% of the market by volume. However, those sales had been going to companies who had the technology for producing those enzymes—that was always a threat.

The threat was made good, when large starch processors, such as ADM, Decatur, Ill., and CPC International, Englewood Cliffs, N.J., who had the technology for enzyme production—but either hadn't used it or who had underutilized capacity—came into the market, initially producing for captive use. The merchant market for other enzyme producers, therefore, shrank, and they lowered prices to try to retain sales. Instead of prices going up as predicted, they fell dramatically, although consumption of starch-conversion enzymes has seen real growth of about 5% per year.

Major enzyme suppliers still dominate the industry. Their market share has declined, however. For example, Novo, which is by far the largest supplier, has seen its market share slip over the past several years from nearly 50% to about 40%. Novo and Gist-Brocades used to control about 65% of the market between them; now Novo, Gist, and Miles Laboratories account for about 70% of the total. These three are major suppliers of starch-conversion enzymes and proteases for detergents.

Novo, Gist, and Miles, with their subsidiaries, make up a strong first tier of suppliers. Over the past five years, however, observe Hepner and Male, there has emerged a distinct second tier of companies, each

Commercial enzymes: who makes them . . .

	% of market
Novo Industri (Denmark)	35–40%
Gist-Brocades (Netherlands)	15–20
Miles Laboratories (U.S.)	5–10
Hansen (Denmark)	5
Sanofi (France)	5
Finnish Sugar (Finland)	5
All others	15
TOTAL	100%

Source: L. Hepner & Associates

. . . and how their markets are split

	Commodity	Specialty
Food applications, including starch, sweeteners, cheese, brewing, fruit, vegetables, baking, and confectionery	40%	15%
Industrial applications, including laundry detergents, paper, and leather	35	5
Animal feed/agriculture	3	2
TOTAL	78%	22%

Proteases lead industrial enzyme market in both volume and value

There are four major categories of industrial enzymes identified by consultants L. Hepner & Associates:

- Proteases. These are used primarily for detergents, to enhance stain-removal capabilities, and account for about 25% of the market.
- Enzymes for starch conversion. These are used for making corn syrups, for example, and for producing ethanol; about 20% of the total market.
- Rennin. These find use in the dairy industry for processing milk and cheese; about 10 to 15% of the market.
- A miscellany that includes such enzymes as pectinase for clarifying wines and other fruit juices, lipase for fat-splitting, papain for beer clarification, and invertase for confectionery.

The oldest techniques for producing enzymes have been variations of surface culture. Surface culture is relatively simple, using trays to hold a shallow amount of liquid, in which the microbial strain is cultured, and into which the enzyme metabolite is exuded. The technique needs a large surface area, as the metabolism needs air from the surroundings. In addition, it is very labor intensive, requiring frequent tray filling and emptying.

At present, there is only one large plant in the West for surface culture of industrial enzymes, owned by Novo's Swiss subsidiary Schweizer Ferment. "No one would dream of building one now on a big scale," says Celia Male, codirector of L. Hepner & Associates. The technique is used for only true "specialty" enzymes, such as some pectinases, microbial rennins, and fungal amylase.

Most industrial enzymes are produced by submerged culture, originally adopted for penicillin in World War II. This culture is basically the same as that used for producing antibiotics (fermentation tanks, centrifuges, filters) involving batch processing. Feedstock is a carbon source, such as starch hydrolysates, molasses, or glucose, on which the organism, such as *Bacillus subtilis*, can grow. Other ingredients in the broth include a nitrogen source, such as corn-steeped liquor or cottonseed meal; mineral salts; and yeast extracts.

The medium is sterilized and the seed

accounting for about 5% of the market. Danish producer Hansen, which specializes in enzymes for the dairy industry as the leading supplier of rennin, has been a member of this group. But the Hepner study identifies two newcomers to the commercial enzyme market: Sanofi, the subsidiary of French oil and chemicals giant Elf Aquitaine, and Finnish Sugar Co.

Sanofi is a newcomer in dairy enzymes, having snapped up a number of small enzyme companies in the food industry, including Dairyland Food Laboratory, Waukesha, Wis. "If you add up all their market share in dairy enzymes, they are just below Hansen," says Hepner. The acquisitions still function as individual companies; they have not yet been pulled together as a central entity.

On the other hand, last year Finnish Sugar jumped in with a joint venture with Nabisco Brands, to produce starch-conversion enzymes. Finnsugar and Nabisco established Starch Processing Enzyme Co. (SPEC), to produce, among other starch-conversion enzymes, immobilized glucose isomerase for making high-fructose corn syrup. The marketing of the enzymes, based on technology originating from Nabisco Brands, is being handled by Fermco Biochemics, Elk Grove Village, Ill., a wholly owned subsidiary of Finnsugar. The enzymes are marketed in the U.S. and other parts of the world to major starch converters, such as ADM.

The third, bottom tier is made up of nearly 40 suppliers that share the remaining 15% of the market. It includes, among others, Pfizer—just a bit below the second tier—producing detergent enzymes in Mexico and amylase in Brazil as well as Japanese producers, none of which have large enzyme sales. The study, for example, notes 10 Japanese companies with total enzymes sales of about $30 million among them.

The Japanese enzyme producers tend to concentrate on the relatively simple but labor-intensive technique of surface culture. U.S. and European producers, on the other hand, use the submerged-culture approach, which is similar to that used for producing antibiotics by batch processing. One of the major Japanese products is pectinase (used, for example, in the brewing industry), most of which is sold outside Japan and much of it to western companies. Japanese producers also use specialty fungal enzymes in their sizable domestic market for sake, miso, and soy sauce.

In the Hepner study, several new commercial enzymes were picked out for further investigation. Lipase is one of the more interesting new products, says Male, and is starting to become a significant product for at least two applications. Microbial lipase helps age young cheese to a more mature flavor. Lipase also is beginning to find use for processing vegetable fats and oils. During transesterification, lipase helps modify fat composition. This enables manufacturers to take a cheap, commercially available fat such as palm kernel oil and convert it, for example, to a cocoa butter analog. "Some interesting companies—such as Unilever, Fuji Oil, and Henkel—are starting to look at enzymic fat modification," she says.

Another "new" enzyme is lysozyme, a bacteriolytic protein found in tears, saliva, egg white, and bacteriophage. It is used pharmaceutically because of its bactericidal properties, and now is being used in foods. Enzyme manufacturers also are looking at markets in the agricultural/dairy industry.

A possible market, for example, might be in milk from silage-fed cows. The milk can contain clostridial spores, which can cause spoilage in cheese, points out Hepner. European farmers, in particular, have become major proponents of silage, a lactic-acid fermentation product. There are several ways to treat spores. One, by nitrate, is allowed by West Germany and the Netherlands, but because nitrates can form nitrosamines, there is pressure to re-culture is added. Fermentation proceeds for about two to three days with aerobic stirring. The classical technique, which provides the bulk of the business, is extracellular production by which the organisms exude the enzyme—their metabolite—into the broth. The key is to minimize the growth of cells and maximize the metabolite.

The yield is roughly 5% protein, a crude preparation but of commercial standard. Enzymes for pharmaceutical or diagnostic applications, however, need to have much higher purity, up to 95% protein.

Some of the more recently introduced enzymes are prepared by intracellular production, in which the key is to grow the biomass and then "reap" it—rupture the cell walls and obtain the enzyme. In contrast to extracellular production, maximum cellular growth is desired. Enzymes from intracellular production are generally more difficult to make. Very few are used in the immobilized state. Chief among those that are is glucose isomerase, used in production of fructose from glucose.

There are already two generations of immobilized glucose isomerase. The first-generation isomerase features immobilized whole cells, in which protein crosslinking agents fix the cells together. The enzyme activity of the crosslinked cells is limited, however, to perhaps 20 to 30 cycles and then a new column is needed.

The second-generation glucose isomerase uses an improved process: The soluble enzyme is immobilized on an ion-exchange cellulose system. In essence, a technician can recharge the column by pouring soluble enzyme over it, which then binds onto the column. Within the past 18 months, Finnish Sugar Co. has landed in the second tier of suppliers of industrial enzymes, on the strength of its second-generation isomerase technology.

Miles Kali-Chemie, Hannover, West Germany, a joint venture of Miles Laboratories and the West German company Kali-Chemie, also has developed a second-generation isomerase. The whole point, says Male, is that "people aren't standing still. They are trying to upgrade their enzymes."

move them. The other way is by lysozyme, which is now permitted by authorities in Italy, France, and Denmark, with West Germany considered to be on the verge of allowing its use. At present, the enzyme is derived at high cost from egg white. Genetically engineered lysozyme, however, could be a commercially attractive product for producers, the study suggests.

Silage is also the market that has made cellulase a commercial product, the report says. It has been suggested that cellulase could be used to break down all cellulose wastes to sugars. Given the abundance of starch sources, that has not proved feasible. However, cellulase is being used as a silage additive. And Finnsugar is promoting glucose oxidase as an additive for silage, to give a high-quality, high-protein product.

In fact, dairy and agricultural products seem to be the great new hope for enzyme marketers. The Hepner study, for example, cites other new applications for enzymes besides lysozyme in the dairy industry. There are applications for enzymes for barley, besides those already used to process barley for brewing; in feeds for poultry and young hogs. The Scandinavians, for example, are using β-gluconase to pretreat animal feed.

There are other potential market opportunities—in the environmental field, for example. One application is in waste treatment. The U.K.'s Imperial Chemical Industries has already developed cyanide hydratase for hydrogen cyanide waste. Finland and Sweden have been investigating the use of ligninase for the pulp and paper industry, seeking to exploit the fact that ligninases are also peroxidases. They degrade lignin and release the chromophoric groups from it, treating wood pulp in an "environmentally kind" way. Genetic engineering companies are working on these now to get commercially viable yields.

Conversely, both Hepner and Male are pessimistic about the chances of enzymes replacing chemical catalysts in reactions. For any chemical reaction, Male points out, an enzyme would have to match or better the reaction efficiency that chemical catalysts can obtain. It hasn't happened very frequently. The study cites one Japanese company that uses nitrile hydratase for making acrylamide from acrylonitrile. It hydrates the double bond, in a very specific enzymic reaction. Similarly, ICI uses dioxygenase enzyme for converting benzene to benzene *cis*-glycol for its polyphenylene production, but that has yet to become commercially attractive.

Even in growth fields, the enzyme market has not proved a gold mine for everyone. Corning last year withdrew from immobilized-enzymes production. It still owns one third of GenenCor, but it has sold a part of the ownership to Staley, as a new partner with Genentech. Corning had wanted to couple an enzyme like lactase to glass. "They were hooked on the technology possibilities," Male analyzes. "But there was no incentive for the users to pay more for immobilized enzymes than for soluble enzymes using the regular technology."

In general, the enzymes business is showing steady growth, which Hepner predicts will continue at slightly less than 5% per year through 1990 (real volume growth, based on 1986 dollars). Even use of starch-conversion enzymes will grow as high-fructose corn syrup, an increasingly important sweetener for foods and beverages, grows.

The U.S. market had a big spurt toward the end of the 1970s, and then began to taper off, although volume growth is continuing. In Europe, the food industry is stuck with high-fructose corn syrup quotas, set years ago at 250,000 metric tons and never revised upwards. In the U.S., by contrast, HFCS production is about 4 million metric tons.

Proteases have been under slightly less price pressure than starch-conversion enzymes, and their use is continuing to grow. The main factor boosting proteases is liquid detergents in the U.S. Many detergents use enzymes to help boost cleaning, which some consumers feel is adversely affected because of low-phosphate content. Enzyme detergents account for about 30% of liquid detergents in the U.S. The Japanese market for detergent enzymes has expanded. The European market is mostly static, although in the U.K. a number of major brands have recently been reformulated with enzymes.

Hepner expects protease prices to hold, with no drastic declines barring any major firms from jumping into the protease business. If one of the large detergent producers were to begin making its own detergent enzymes, that would put massive pressure on the market. One potential worrisome development: European detergents giant Henkel has announced a joint-venture protease plant with Biochemie from Austria. It was scheduled to come on stream in 1986–87, and started up in the past few months.

Throughout the industry, suppliers are working to upgrade their enzymes to give them specialties status, thus differentiating them from commodities that are subject to the same kind of price cutting that hurt starch-conversion enzymes.

In addition, they are looking at capacity utilization and yield improvement. As Hepner observes, "If a supplier can get yield improvement, that is equivalent to adding capacity. Any new company getting into the enzymes business would have to put up a new fermentation plant; these are high-cost and very capital-intensive. The investment might be warranted for an antibiotics fermentation plant. Return on assets is much higher for something like penicillin, because the world market for penicillin is much larger. Enzymes, on the other hand, are not that big a market." □

Efforts toward Bhopal settlement pick up steam

From the shape of the news concerning the ongoing saga of Bhopal, the two sides—the Indian government and Union Carbide—seem poised to square off in the court battle that is set to take place in Bhopal itself. India has just filed its affidavit in Bhopal district court. The amount of damages are unspecified; Indian sources have said a specific dollar figure required by the court will be given in some months, once various studies are finished. Behind the scenes, however, another scenario appears to be taking shape, one aimed toward settlement.

To recap the Bhopal toll, more than 2000 are dead—the "more" probably numbering about 1000, since even today an average of two persons exposed to the methyl isocyanate (MIC) gas are dying each week and a few hundred may simply be unaccounted for. In addition, India says another 500,000 have claimed injury from exposure to the gas that spurted from the tank at Carbide's pesticide plant the morning of Dec. 3, 1984. There is debate about the long-term toxicological and genetic impact of MIC, but intestinal problems, lung damage, and mental disorders are facts of life for thousands.

The current mood around the community of litigants and interested parties in this aftermath stage is that neither side wants to go through an Indian trial. Some believe that only a trial will serve to bring out the truth about what happened that night. But a decision, Indian sources now say, would take at least five years, and could take 15. The process would be costly, and information unflattering to both sides would probably emerge. Thus, a serious independent effort toward settlement has now begun.

Says Bhopal-native Paul Shrivastava, now an associate professor of management at New York University's Graduate School of Business Administration, "All the Indians want is a face-saving offer to demonstrate to their people that they are not selling out. The amount of settlement is not the real source of dispute. What Union Carbide has offered and what India expects are not that much different. India is not interested in any lump sum."

The belief that dollar sums are not the issue was confirmed by C&EN last week in discussions with various Indian sources. Said one, "We really are not that far off in the settlement amount." He says Carbide made an offer that reached $400 million in August 1985, when a settlement seemed imminent. At that time, the Indian demands hovered around $1 billion, at which point negotiations collapsed. Last January, Carbide came to a $350 million agreement with U.S. lawyers representing the Bhopal victims. But the Indian government, never having been part of those negotiations, scorned the offer. Time moderated tempers, however, and India, say reliable sources, now will be satisfied with $500 million spread over seven to 10 years. Now the two sides must be brought together to end the whole battle.

"Neither India nor Union Carbide know of any process by which a dialogue can be initiated whereby both sides can save face," explains Shrivastava. "We think a forum is needed, and I am working on ideas on how such a meeting could be initiated."

Shrivastava has recently returned from Bhopal and New Delhi where he met with officials to lay early plans for a mediation effort. A few days ago he breakfasted with Union Carbide chairman Warren M. Anderson to broach the idea of the initiative. "I met him only for the first time," says Shrivastava, "but he seemed anxious to pursue the whole thing. Even though I've written and said a lot of things critical of him, I was still very impressed with his sincerity and concern for the victims. In fact, in some cases the level of concern he showed was higher than that of many of the politicians I met in Bhopal and New Delhi."

Last week Shrivastava was completing a 14-page mediation proposal. It will go to principals at Carbide and to officials in the governments of India and Madhya Pradesh, the Indian state where Bhopal is located. The aim is to bring both sides together in December. He does not feel lawyers can handle the mediation because the case is now in the Indian court system and legal protocol conspires against that route.

The latest public update on the Bhopal situation, at which some hints of settlement eked forth, came 10 days ago at an international conference on industrial-crisis management organized by Shrivastava at New York University. Carbide's Anderson, who has lived full time with the disaster, was a major participant and seemed eager to come to a settlement. In the audience of mainly academics were several critics of Carbide.

In his presentation, Anderson made a point of stressing as he has in the past that Carbide was not interested in any protracted trial. "My feeling about litigation was stated right from the word go," he said. "If you want to litigate victim liability I'll take as long as it takes to do it. But I want to avoid that issue. I accept moral responsibility.

"Our name was associated with that operation. People were hurt. Let's solve that problem. Let's not get caught up in this morass of litigation and responsibility because an individual might want to know 15 years from now what exactly did happen and who was to blame."

Anderson's presentation was an overview of Carbide's response to both the Bhopal disaster and the aldicarb oxime leak at its Institute, W.Va., plant just nine months later. He again repeated why he feels sabotage was the main cause of the Bhopal accident. He said Bhopal made corporations much more careful about seeking technology transfer agreements with Third World countries. And he called for what would essentially be no-fault global standards covering compensation for industrial disasters so that litigation can be avoided.

Carbide is more certain than ever, Anderson said, that entry of water into tank 610 containing MIC was a deliberate act. When the company studied core samples taken from the tank after the leak, "we avoided completely this issue of sabotage. We attributed no political overtones to this whatsoever, but we discounted any sequence of events that possibly could have introduced water to that tank other than a deliberate act. Now, lots of time has gone by, and we have now been able to look at logs and talk to some people. Our conclusions remain that a large amount of water was in fact added to that tank, and it was deliberately done so by a disgruntled employee. We are not finished with our work there. The information we get will be shared with the Indian government when it's appropriate."

Anderson: avoid protracted trial

Anderson was quickly challenged on several points by the commercial consul for the Indian Consulate in New York City, Talmiz Ahmad. "Mr. Anderson has made the point that Union Carbide offered a generous settlement," Ahmad said. "Nothing could be further from the truth. They offered at different times five separate settlements of differing character. Which of these is generous we are at a loss to find out. But they are significantly lower than what the Indian government authorities including Air India have paid to their own victims from time to time. And that was without regard to questions of liability.

"He has suggested that the Indian government wanted the trial in the U.S. because of attractions of multibillion dollar compensations. I can assure the assemblage here that at no stage had we thought in terms of billions of dollars. And he is aware that the Indian government's claim has been significantly lower than $1 billion and in fact is only slightly more than Carbide's last offer to us. But it has been interested in prolonging this litigation and in continuing this problem."

Another Anderson critic was Charles Perrow, a Yale University sociologist who has been focusing studies on industrial disasters. "Union Carbide tried to present themselves as victims of something as simple as the Johnson & Johnson Tylenol case. They are saying somebody came along and sabotaged our plant and it really wasn't our fault. They are also saying that it was quite a different situation than at Institute. It's not.

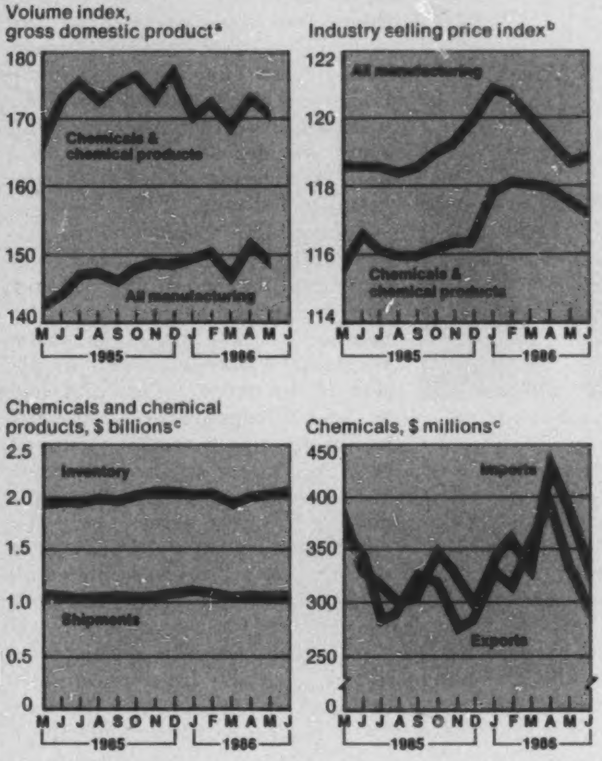
"The question isn't how the water got in. Water can always get into anything. The problem is how you design things for what happens when water does get in. There would have been no severe explosion if the refrigeration unit had not been disconnected, or the gauges had been properly working and had been monitored by the personnel. There would have been less of a disaster if various actions were taken at the first smell of MIC, or if the scrubber had been large enough to handle a large excursion, or if the scrubber had even been in service, or if the water sprays had been designed to go high enough to douse the emission, or if the flare tower had been of sufficient capacity to handle a large excursion that you might expect from a large tank.

"That's a long list of deficits. Sabotage may be the most reasonable explanation for the water getting into that tank. But it's the most inconsequential part of the accident."

What is not inconsequential, however, is the move toward a settlement. When interviewed at the conference, Carbide officials were reluctant to clarify how the sabotage issue could affect the legal proceedings. Ronald S. Wishart, vice president for public relations, observed how "symbolism" is playing a powerful role in how the two sides relate. Shrivastava could well be the type of person who could act as the "credibility symbol" needed. He relates well to the Carbide executive team. He is an Indian native. He was a neighbor of some of Bhopal's victims. Currently he is working at it and doing the Hindu equivalent of keeping his fingers crossed.

Wil Lepkowski, Washington

Canada's Slowing Economy Hits Chemicals



[a] Seasonally adjusted, 1971 = 100. June 1986 data not available. [b] 1981 = 100. [c] For 1985, $1.00 = $1.36 Canadian; for 1986, $1.00 = $1.40 Canadian.
Source: Statistics Canada

Although sales and earnings were up for most Canadian chemical companies during the first half of the year, chemical company executives know that their worries are not behind them.

With the exception of ethylene and low-density polyethylene, gains in Canadian chemical production have been far from spectacular. In fact, output is down for many key products.

First-half chemical exports—so vital for many of the major petrochemicals produced in Canada—are down. Chemical imports, meanwhile, are up.

To make matters worse, the Canadian economy is slowing down. The big question now is: What lies ahead? Some Canadian economists say their economy will perk up again in 1987. Others believe a recession lies ahead.

Canada is now in its fourth year of economic expansion, but the economy is losing some of its steam. Consumer spending, which helped carry the Canadian economy recently, is tapering off. Capital spending is down, particularly in the oil sector, which has been hit hard by low oil prices.

The chemical industry, however, is increasing its capital spending this year more than 50% to $930 million ($1.00 = 1.40 Canadian dollars, average for first six months of 1986), according to Statistics Canada. Most of this investment is going into ammonia, hydrogen peroxide, and sodium chlorate plants.

Statistics Canada also notes a slowdown in manufacturers' shipments over the past few months. For the chemical industry, midyear shipments weren't appreciably higher than they were a year ago and they are down about 3% from January. Chemical inventories, meanwhile, have inched upward slightly.

With so little momentum in the economy at home, some Canadian economists believe that trade will be a critical factor in determining which way the economy turns. Unfortunately, overall Canadian trade was weak in the first half. That certainly is true of chemicals. First-half chemical exports dropped 4.9% (based on Canadian currency), while chemical imports rose 8%. As a result, last year's $109 million surplus in chemical trade was transformed into a $161 million deficit this year.

The lower chemical exports reflect poor prices and depressed export markets. This is especially true of the U.S., which gobbles up two thirds of all Canadian chemical exports. The increase in Canadian chemical imports was spread evenly across the board, with the exception of fertilizers. Biggest gainers, however, were specialty chemicals such as toiletries and drugs.

If the U.S. economy rebounds, Canadian exports, including chemicals, probably will improve and give the overall economy a much-needed boost.

Earl Anderson, New York

Ethylene, polyethylene are only big gainers

Production, thousands of metric tons	1985	First six months 1986	First six months 1985	% change 1985–86
ORGANICS				
Ethylene	1744	942	842	11.9%
Propylene	648	276	307	−10.1
Benzene	688	298	317	−6.0
Toluene	473	167	231	−27.7
Xylene	415	165	208	−20.7
PLASTICS				
Polyethylene, low density	733	433	341	27.0
Polyethylene, high density	229	119	116	2.6
Polystyrene[a]	178	94	91	3.3
INORGANICS				
Hydrochloric acid	158	74	78	−5.1
Nitric acid	1128	585	571	2.5
Phosphoric acid[b]	627	342	332	3.0
Sulfuric acid	3890	1959	2000	−2.1
Ammonia, anhydrous	3620	1933	1737	11.3
Ammonium phosphate	1301	710	691	2.8
Chlorine	1424	744	700	6.3
Sodium hydroxide	1589	816	778	4.9

[a] Includes acrylonitrile-butadiene-styrene. [b] 100% P_2O_5. **Source:** Statistics Canada

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SEPTEMBER 22, 1980

CHEMICAL & ENGINEERING NEWS

Scientific news from the Anaheim ACS meeting

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LETTERS

CHEMICAL SAFETY

Sulfur trioxide

SIR: We would like to report an accident involving the use of sulfur trioxide. This material is being used for the sulfonation of polymers in solution and a fresh ampoule is being opened for each reaction. We have been disposing of the unused portion of sulfur trioxide by dripping a small quantity of water into each open vial every day. The resulting product is sulfuric acid and several weeks are required to complete the dilution process.

Recently, a vial that had been filled with water exploded when turned upside down for collection in a large waste container. Concentrated sulfuric acid was blown all over the laboratory and fortunately no personnel were injured. It appears that this water dilution technique results in a density gradient within the vial in which highly concentrated acid rests on the bottom and pure water floats near the surface. When agitated, these two layers mix to generate an explosive heat of solution and an enormous pressure buildup. We would therefore advise against this disposal method for researchers using anhydrous sulfur trioxide.

Paul B. Willis
Senior Project Manager
Springborn Laboratories Inc.
Enfield, Conn.

History of chemistry

SIR: Alan McClelland's comment on chemical education (C&EN, June 23, page 70) struck some familiar bells (to continue, loosely, his musical analogy). Here at the Center for History of Chemistry (CHOC), we also believe that an important goal for the chemical community is to educate the nonchemical "audience" about the place of chemical issues in daily life. This conviction was shared by the ACS Board when it agreed to cosponsor CHOC in 1982.

History, we have found, is an effective tool for helping students and the general public explore chemical issues. Partly, this is due to the inherent interest that stories about the past hold for many people. But, more important, the history of chemistry provides a framework for understanding the interaction between society's sometimes competing demands and chemistry's ability to respond to those demands.

Various CHOC activities have shown how this can be done. Our traveling exhibit on Joseph Priestley explores the relationships among his politics, his religion, and his science. Our exhibit, "Scaling Up," illustrates the interplay of economic, political, and technical goals in various industrial processes. Our recent publication on polymer pioneers examines the relationship between the opportunities and constraints on individual scientists and the science that they developed. Our oral history program of autobiographical interviews with such leading figures as William O. Baker, Arnold O. Beckman, Carl Djerassi, Herman Mark, Carl Marvel, Charles C. Price, and others document the human side of chemical inquiry, invention, and entrepreneurship. And by collaborating closely with the ACS Eminent Chemists Videotapes Program we also help to provide other working tools based on history for those interested in illustrating the complex relationships between social and technical issues.

It is clear that the audience—and even the "performers"—of chemistry can obtain a richer sense of chemistry's role in the world if ACS actively supports audience education. We applaud McClelland's comments on these issues.

Arnold Thackray, *Director*
Jeffrey L. Sturchio, *Associate Director*
Center for History of Chemistry
Philadelphia

Odorized explosives

SIR: W. V. Ligon's concept of odorized explosives (C&EN, July 21, page 3) as a means to foil terrorism is an intriguing one. However, if an odorant was chosen for human nasal perception, I would tend to disagree with Ligon's contention that terrorists would "self-destruct" by making their own explosives; rather they would probably find clever ways to circumvent the odorant problem. I would suggest that the idea might have more merit if an odorant were used that could be readily perceived, at low concentrations, by properly trained dogs, but not by the human nose. Such a technique has apparently been quite effective with various aspects of marijuana traffic control.

Richard D. Stacy
Tucson

Corrections

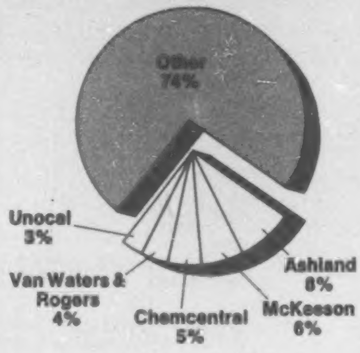
- Aug. 4, page 13: American Cyanamid's agreement with Iowa Limestone Co. covers calcium carbonate, not calcium carbide, deposits.
- Aug. 18, page 11: NSF's fiscal 1986 science education budget is $84.5 million, not $53.2 million, because of a $31.3 million transfer from 1985 funding.

Chemical sales via distributors growing

Chemical sales through distributors in the U.S. are forecast to show real growth of about 5.2% per year through 1990, hitting a total of $12.6 billion in 1990 in 1985 dollars, according to a recent study by Charles H. Kline & Co. of Fairfield, N.J. That means chemical distributor sales will grow about 50% faster than overall chemical consumption.

The Kline study notes several driving forces behind the greater sales growth by distributors. For instance, producers are consolidating sales forces and expanding product authorizations to reduce selling costs; producers often realize greater profits on certain products by selling through distributors; customers are maintaining leaner inventories and requiring shorter delivery times; distributors are expanding the services and products that they offer to meet customer needs; and distributors are meeting higher levels of professionalism.

Five firms have about 26% of distribution business



Total 1985 sales = $9.8 billion

Source: Charles H. Kline & Co.

More than 1000 industrial chemical distributors do business in the U.S., according to the Kline report. Although the majority have annual sales of less than $10 million, five firms—Ashland, McKesson, Chemcentral, Van Waters & Rogers, and Unocal—together accounted for nearly $2.5 billion of the $9.8 billion total industrial chemical sales in 1985. Kline predicts that future mergers and acquisitions will result in fewer, but larger, firms in the future.

The study says that, increasingly, chemical producers use distributors as an integral part of their total marketing effort. It adds that, although chemical distributors have existed for decades, their importance has increased in the past decade as producers have increasingly seen distributors in a positive light and consider them an extension of the producers' sales and marketing effort.

The report is available on a subscription basis from C. H. Kline & Co., 330 Passaic Ave., Fairfield, N.J. 07006.

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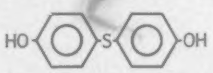

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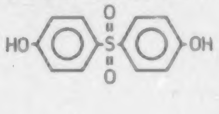
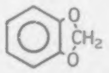
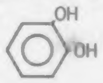


- 1,2 METHYLENEDIOXYBENZENE



- EXTRA PURE CATECHOL



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Outlook Brightens for West European Chemical Firms

Major restructuring, led largely by state-controlled companies, is putting firms in better position to meet overcapacity, other problems

Earl V. Anderson, C&EN New York

The Western European chemical industry is alive, if not kicking as strongly as it should be. It is running into new challenges even before the last ones have been fully overcome. But, according to one respected observer of the European chemical scene, "the prospects of survival, even of growth, are looking better now than for many a year."

Stuart H. Wamsley, director of international chemical research for Greenwell Montagu & Co., London, admits that he hasn't been exactly sanguine about the European chemical industry's prospects in the past. But, he warned his audience at the World Chemical Congress of Marketing & Business Research in Newport Beach, Calif., "This time you are in for a surprise."

Wamsley thinks that a new crop of chemical industry leaders are more willing to learn from lessons of the past. The industry, he says, almost brought about its own demise because of its "horrendous and perpetuated" mistakes. It no doubt will make more mistakes, Wamsley concedes, but he thinks that the first "real flickerings" of a much brighter future are beginning to appear.

Only now is the Western European chemical industry starting to benefit from the substantial drop in oil prices, even though the price cuts started nine months ago. First, the industry faced hefty inventory writedowns. More important, customers who knew that prices would inevitably fall refused to buy petrochemicals and plastics. As a result, says Wamsley, West European chemical volume demand fell 2 to 3% during the first few months of the year. Selling prices tumbled. Chemical company profits dropped 10 to 20% in the first quarter. The second quarter was not much better.

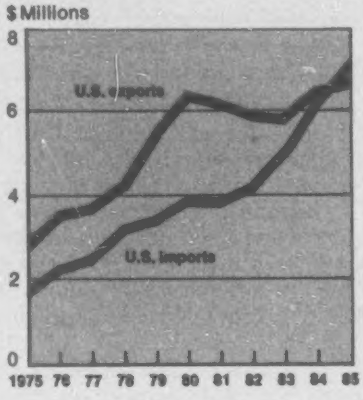
Now, Wamsley sees the situation changing. Because their own stocks are getting low, customers are being forced back into the chemical market. As a result, prices are stabilizing. With almost 25% of Western Europe's ethylene capacity scheduled for maintenance shutdowns during the second half, a fear of shortages is pushing up ethylene prices. Derivatives prices are sure to follow.

When the full benefits of lower oil prices hit the industry, the results, Wamsley says, will be massive. He points to Imperial Chemical Industries' profit margins, which rose from 12.0% in the fourth quarter of 1985, to 12.8% in this year's first quarter and to 15.4% in the second quarter. In the U.K., indexes of chemical input prices have declined 20% from their peaks, while output prices have continued to rise. These trends, says Wamsley, are now showing up in profit margins.

Plants producing ethylene and the major thermoplastics in Western Europe now are running at about 90% of capacity—sometimes higher, he says. But producers shouldn't be too complacent about that record. Much of the growth in output has gone into exports, not into the domestic European market.

Western Europe exports almost 50% of its chemical output, compared to only about 10% for the U.S. It was export volume, Wamsley contends, that was largely responsible for the European chemical industry's growth in the past couple of years. Thus, although output was rising, it did not keep pace with domestic demand. As a result, chemical imports grew faster than exports. That was true even when currency exchange rates were supposedly favorable to European producers. Now that exchange rates are less favorable, the situation is likely to get worse, Wamsley says.

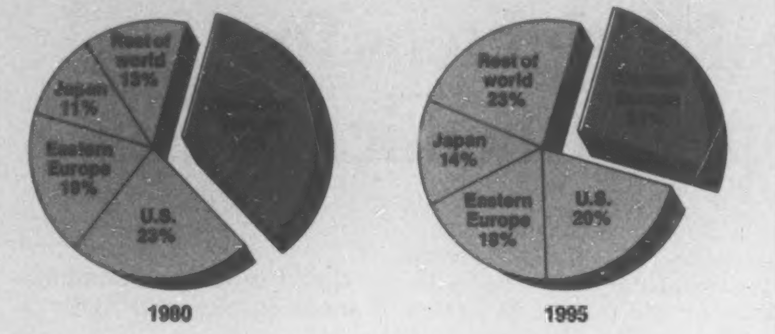
West Europe has chemical trade surplus with U.S.



Source: Department of Commerce

There's also no doubt in Wamsley's mind that Western Europe's share of the world's basic petrochemical production will shrink as plants continue to come on stream in new producing areas. "Europe cannot justify having 12 of the world's top 20 [chemical] companies," says Wamsley, when Africa, the Middle East, and the rest of the developing world have more than 80% of the world's oil and gas reserves, but sell only 13% of its petrochemicals. Europe's share of petrochemical production could drop from about one third to no more than 25% by the end of this decade.

Western Europe's share of world chemical sales will shrink



Source: Greenwell Montagu & Co.

However, don't write Western Europe off as a petrochemical producer. Even with a real growth in chemical demand of only 2 to 3% per year and an inflation rate that would bring chemical sales growth up to 5 or 6%, chemical sales in Western Europe would increase from about $200 billion to about $400 billion in 1995. Such an enormous, heavily concentrated market makes it politically out of the question to visualize anything but a large, European-based industry serving at least a major portion of this demand.

If, however, European chemical producers retain their present product and site mix, Wamsley is certain that low growth will be the norm. It also will take several years to mop up existing overcapacity. In fact, these companies will have to go through another period of "traumatic restructuring," if not by design, he says, then by necessity.

He thinks that this restructuring already is happening in Europe and that it is being led largely by the state-owned or state-controlled companies. Those companies did not participate in the last round of industry restructuring.

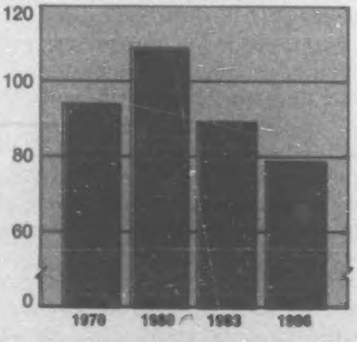
A lot of chemical industry restructuring occurred between 1980 and 1982. There are, for instance, far fewer producers of the major thermoplastics in Western Europe now than there were in 1980. Even so, Wamsley believes that there still are too many. Fewer producers, he points out, doesn't always mean an equivalent drop in capacity. There now are only 16 producers of polyvinyl chloride (PVC) in Europe, a drop of 36% from a few years ago. However, only 13% of Europe's PVC capacity has actually been shut down.

Given the many problems facing the European chemical industry, why hasn't it rationalized itself further over the past few years? Wamsley thinks that, in 1983, a revival in chemical demand stopped restructuring in its tracks. More needs to be done, he says, and until recently, odds were that the industry would not make enough progress before the next economic downturn. "Producers will reduce capacities only when they are losing big money," he says.

Another reason why the last capacity shakeout didn't go far enough is the large amount of capacity controlled by state-owned companies. They now control about 40% of Europe's capacity, compared with only 30% a few years ago. "These companies are not known for their willingness to shut down plants," says Wamsley.

Number of resin producers in West Europe is falling

Number of producers of major resins[a]



[a] Includes producers of low-density and high-density polyethylene.

So where does Western Europe's chemical industry go from here? Surprisingly, answers Wamsley, its petrochemicals and plastics producers seem embarked on another major round of restructuring. If it continues, he says, it will go a long way toward solving Europe's overcapacity problem.

A major factor in this awakening, he says, is that many European commodities producers have seen their cash flows and cash reserves deteriorate badly. This is particularly true of the state-owned companies but, this time, he says, the governments will not or cannot bail them out. The only solutions are to restructure, cut capacity, form a joint venture, or disappear completely.

Obvious examples of what is happening include the complete reorganization of the Spanish state-owned companies, the ICI-Enichem deal in PVC, the proposed Enichem-Montedison deal in petrochemicals, and the BP/Atochem joint venture in polypropylene. The list is long. It involves large tonnages. And it's not completed yet. When it is, Wamsley thinks that European producers will be able to cope with the problems posed by the new petrochemical producers of the world.

Yet there always is more that can be done. For instance, Wamsley thinks that there are still two ethylene crackers that should not be operating in Europe because they are not economic. One is the CdF Chemie unit at Dunkirk; the other is Companhia Nacional de Petroquímica's Portuguese cracker. Scrapping them would remove another 550,000 metric tons of annual capacity—4% of Europe's total.

Wamsley believes that if European producers want to regain the initiative from their customers, they must achieve a better supply-demand balance. Only then will there be stable prices and stronger profit margins. Wamsley suggests looking at titanium dioxide. After 15 years of disaster, producers finally achieved a true supply-demand balance. Prices rose about 45% in 18 months. □

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More scientific news from ACS meeting in Anaheim

SEPTEMBER 29, 1986

CHEMICAL & ENGINEERING

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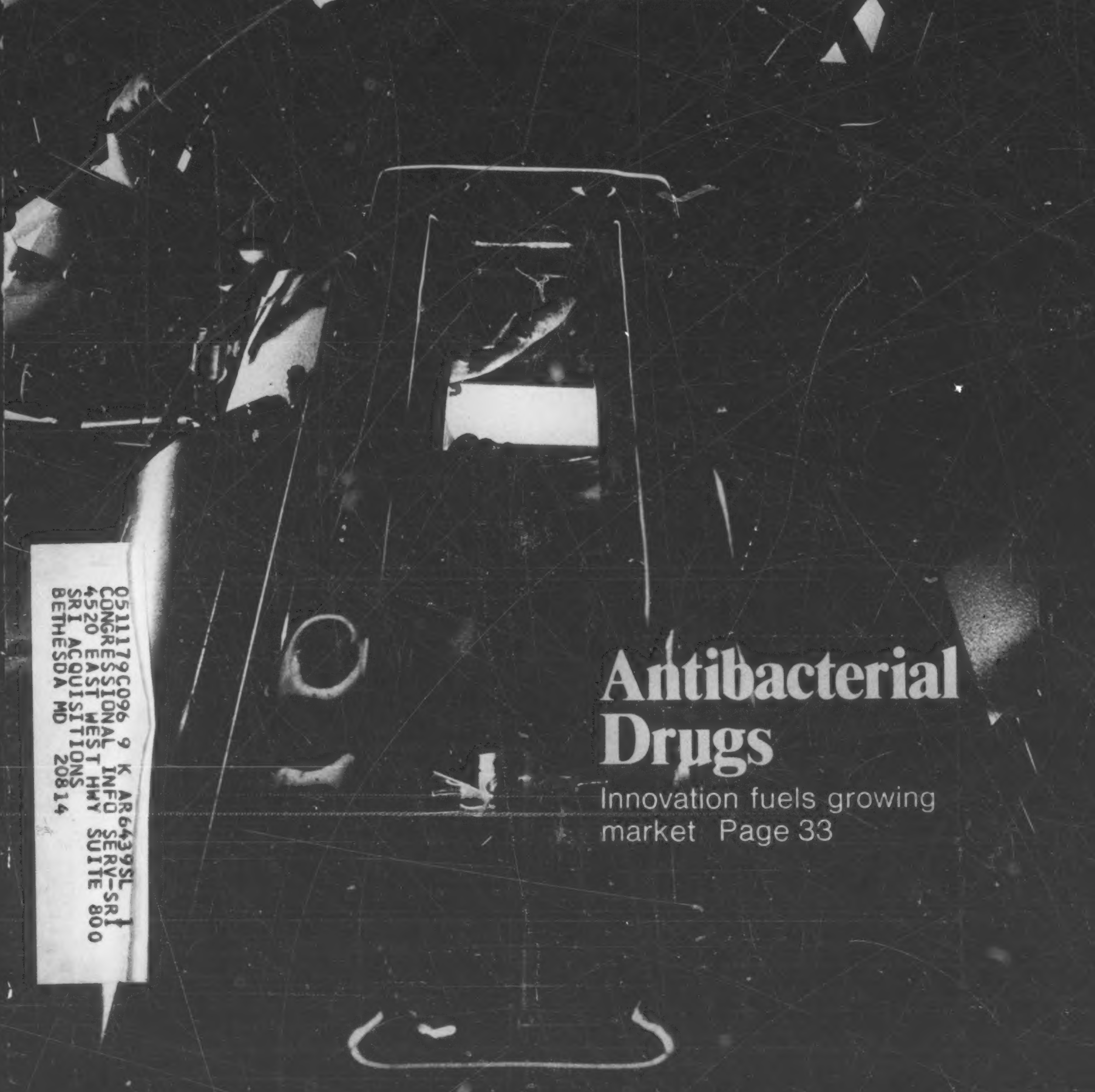

Antibacterial Drugs

Innovation fuels growing market Page 33

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CHEMICAL & ENGINEERING NEWS

SEPTEMBER 29, 1986

News of the Week

- **Limited success of azidothymidine in clinical trials is leading scientists and health officials to reassess testing procedures in treatment of AIDS.** Page 6
- **Air Products & Chemicals names its president, Dexter F. Baker, to succeed Edward Donley as chairman and chief executive officer.** Page 7
- **National Distillers & Chemical's planned purchase of Enron Chemical and divestiture of spirits and wine segment will make it nation's largest producer of polyethylene and shift its focus to chemicals.** Page 7
- **W. R. Grace & Co. settles Woburn, Mass., drinking water contamination case out of court, several months after jury found Grace guilty of polluting wells.** Page 8

Cover: Pilot-plant-scale fermentation unit at Squibb Institute for Medical Research, Princeton, N.J., used to help identify and characterize bacteria and to find optimum conditions for producing new antibiotics

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Business

New ethylene plants will not be needed worldwide through late 1990s, according to Exxon vice president. Page 12

International Business

Brazil's petrochemical industry looks ahead to long-term growth; needs investment capital to satisfy growth in domestic demand. Page 14

Government

Research universities worry about financial future because of possible changes in tax code and government funding policies. Page 17

Science

From the ACS meeting: Biotechnology Secretariat inaugural program; new anticonvulsant agents; promising new agents for body imaging; chemistry's tarnished public image; electron transfer between proteins probed; excitation advances in FT/ICR mass spectrometry; environmental effects of organosilicon compounds; data system that links structures and reactions; indicator for perishable products; immobilized colloids as effective catalysts. Page 19

Education

Also from the Anaheim meeting: Students' beliefs affect the way they approach chemistry; top-rated universities' chemistry departments still show little interest in including polymers in their programs. Page 79

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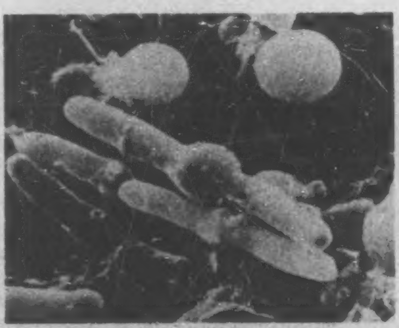
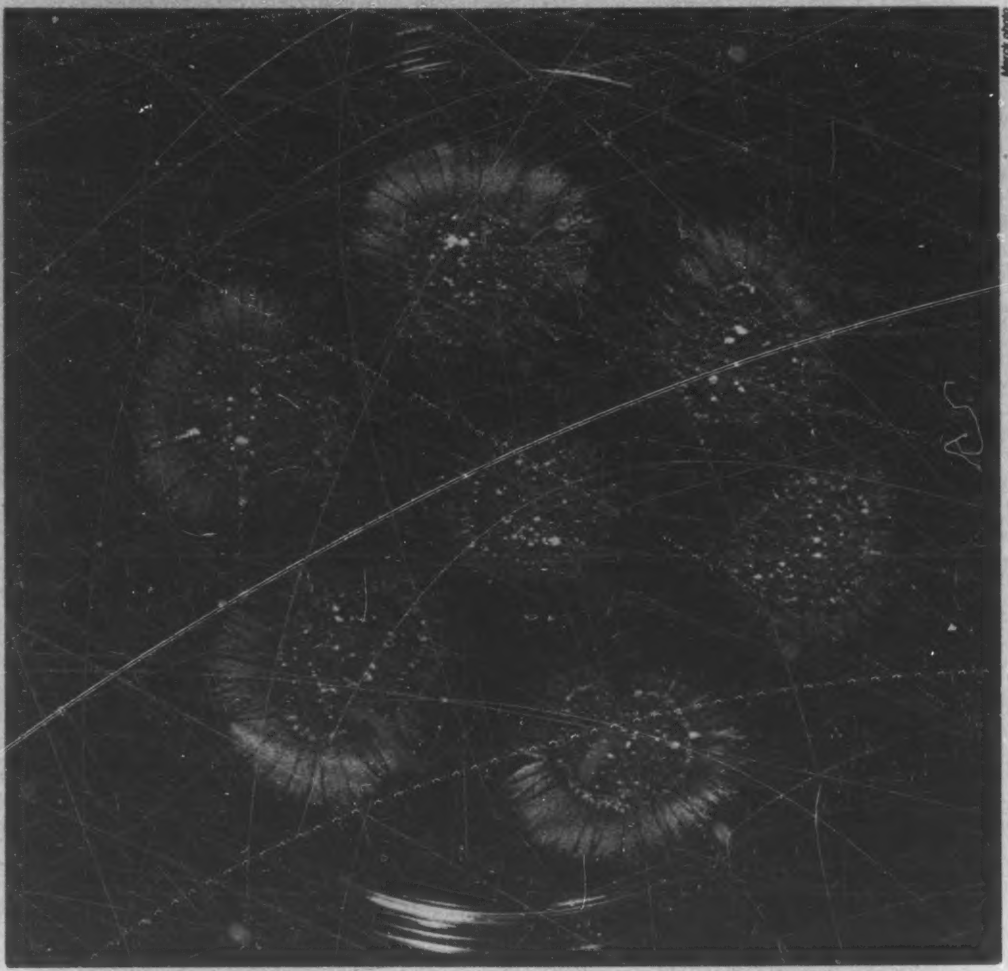
Congressional fellows for 1985-86 express satisfaction at end of year's work on Capitol Hill. Page 84



Product Report

Antibacterial drug market, fueled by innovation, is experiencing feverish growth worldwide; in next five years more than three dozen new antibacterials will be processed by FDA. Page 33



The mold Streptomyces cattleya *produces the broad-spectrum antibiotic, thienamycin*

Innovation Fuels Growing Market For Antibacterial Drugs

Stephen C. Stinson, C&EN New York

Research on and development of antibacterial drugs have reached feverish levels of activity worldwide. In the U.S. alone, more than three dozen new antibacterials will wend their slow routes through the Food & Drug Administration in the next five years. True, cost-cutting pressures from governments combined with price competition from generic forms will erode sales and profits in this period.

But higher prices for new, more potent, patent-protected antibacterials will more than offset these losses. David K. Crossen, security analyst at the investment management firm of Sanford C. Bernstein & Co., New York City, estimates that U.S. sales will grow 5% yearly from $2.5 billion in 1985 to $3 billion in 1990.

Some of the fuel for the current push in antibacterials comes from the seemingly inexhaustible supply of molecular structures in nature. Prospecting among new molds, chemists at Merck & Co. found thienamycin, a penicillin that lacks the usual heterocyclic sulfur atom. The resulting carbapenem class of antibiotics is the object of dogged research everywhere, with Merck's own injectable product having the broadest spectrum of any antibiotic known to date.

And at Squibb Corp., sifting through countless soil samples has yielded molds that make antibiotics with bare azetidinone rings. So even the fused five- and six-membered rings of β-lactam antibiotics, let alone their heterocyclic sulfur, are unneeded for activity. Other firms have rushed to develop compounds in this monobactam class, though Squibb will come to market first with its injectable aztreonam.

More fuel to develop new antibacterials comes from purely synthetic chemistry. Medicinal chemists have regained confidence that quinolones can be developed with broader spectra and lower incidence of side effects than earlier compounds of the class.

Richard R. Vietor, security analyst at Merrill Lynch in New York City, surveyed prospects for the newest generation of quinolones, which are oral drugs. Vietor predicts that Merck will be first into the U.S. market with norfloxacin, followed by the enoxacin of Warner-Lambert, and then by the ciprofloxacin of Miles Laboratories.

Although the bounty of nature and the inventiveness of medicinal chemists provide the push that brings new antibacterials to market, other forces are pulling them along, too. One force is cost-containment measures. The U.S. government has set up diagnostic-related groups (DRGs) in the medicare system, under which amounts reimbursed will be fixed according to the disease diagnosed rather than the actual amount spent to treat it. Crossen of Bernstein & Co. has analyzed the effects of DRGs on antibacterials.

Squibb workers collect soil samples in Pine Barrens region of New Jersey

Crossen expects hospital managers to shorten the length of patient stays over the next five years. Thus, doctors will use fewer injectable and more oral antibacterials to treat infections because injectables must be given by medical personnel, whereas patients can take oral prescriptions at home. In addition, doctors must order costly laboratory tests to monitor injectable aminoglycoside antibiotics to avoid possible damage to kidneys and hearing. This growing preference for oral drugs will pull the quinolones along, as well as oral forms of such newer antibiotics as monobactams.

A second force exerting a pull on new antibacterials is continuing concern over development of resistant bacteria. As hospitals turn to wide use of broad-spectrum antibacterials, populations of bacteria resistant to each of these evolve. Hospital personnel cannot help but be carriers of resistant bacteria. About 6% of patients acquire a bacterial infection while in the hospital.

But cost-containment measures also can work against antibacterial drug sales. For example, Crossen already sees that hospitals are led to use fewer antibacterials before surgery as prophylaxis against infection.

Another effect of cost containment is that hospitals are limiting the number of antibiotics included in hospital formularies as available for use. Crossen sees sales and profits eroding as drug firms bid to get their antibacterials listed. Such competition will intensify as a large number of new antibacterials come to market by 1990, he says. Another factor is the great number of broad antibacterial drug categories, which may be represented on formularies by only a few compounds each.

Examples of newer antibacterials that satisfy these concerns are Hoffmann-La Roche's injectable cepha-

Antibacterials: what they are

This Product Report covers drugs with antibacterial activity, which include the antibiotics. Medicinal chemists call an antibiotic any antibacterial compound that comes from such natural sources as molds, or a compound that has a molecular structure analogous to natural antibacterials. Thus, penicillin G is an antibiotic produced from fermentation of *Penicillium chrysogenum*. Aztreonam is also an antibiotic, even though made synthetically, because soil molds produce compounds that have its basic azetidinone nucleus. Antibacterials that are not antibiotics include quinolones, nitrofurans, and sulfa drugs.

This report does not include antifungal, antiviral, or antiparasitic drugs, though some antibacterials are active against some of those infection types also. For example, penicillin G is the drug of first choice for syphilis, which is caused by a spirochete. And tetracyclines are preferred against the rickettsia of Rocky Mountain spotted fever.

Some compounds originally discovered by their antibiotic activity are later found to be anticancer drugs also. Mitomycins, produced by fermentation of *Streptomyces caespitosus*, apparently inhibit replication of bacterial DNA by crosslinking the strands, and may damage DNA of human malignant cells in the same way.

losporin, ceftriaxone; Merck's injectable carbapenem formulation, Primaxin; and Pfizer's injectable cephalosporin, cefoperazone.

Ceftriaxone has the longest serum half-life of any cephalosporin, which means that doctors can give it only once daily to patients whose infections respond to it. This is important, because nursing and pharmacy costs combine with drug costs to make up the total cost of antibacterial therapy, so fewer doses are less expensive overall.

Primaxin contains a thienomycin derivative called imipenem, which has the broadest spectrum of any antibacterial. That means that doctors can give Primaxin as a single drug in emergencies when laboratory tests have not yet identified

Chemicals celebrate a century of combat against bacteria

Ever since doctors found that bacteria cause disease, chemists have sought and perfected the "magic bullets" to kill them.

1865. Joseph Lister, surgeon at the Glasgow Royal Infirmary, uses aqueous phenol to disinfect instruments, wounds, incisions, and air. By 1869 mortality on his ward drops to 15% from 45%.

1876. Prussian country doctor Robert Koch isolates bacteria from animals with anthrax, cultures them, and shows that they induce the disease in other animals. His classic method of proof finds wide use in linking microorganisms to disease, and he receives the Nobel Prize in 1905.

1877. Louis Pasteur, physiological chemist at the École Normale Supérieure, Paris, finds that invading atmospheric bacteria kill anthrax germs in cultures, that anthrax germs cannot survive in soil, and that animals infected by other germs are not infected by anthrax. This antagonism among microorganisms is later called antibiosis.

1898. Bacteriologist Rudolph Emmerich of the University of Munich [illegible] bacteriocidal pyocyanase from *Pseudomonas aeruginosa*. Though moderately successful in patients, pyocyanase is abandoned as unreliable and toxic by 1913.

1910. Paul Ehrlich, director of the Royal Institute for Experimental Therapy, Frankfurt, tries 605 arsenic compounds against microbes and finds that No. 606, arsphenamine, is effective against *Treponema pallidum*, the syphilis spirochete. Ehrlich, who had won the Nobel Prize in 1908 for work on immunology, was inspired by preferential staining of certain tissues with methylene blue. He theorized that some chemicals, which he called "magic bullets," might bind to and kill bacteria without harming human cells.

1928. Pathologist Alexander Fleming at St. Mary's Hospital, London, finds that *Penicillium notatum* molds contaminating his Staphylococcus cultures kill them. He names the inhibiting substance penicillin and realizes its importance, but lack of funds prevents him from isolating it for tests.

1932. Pathologist Gerhard Domagk of Farbenfabriken Bayer's laboratory in Wuppertal-Elberfeld, Germany, tries thousands of dyes against bacteria and discovers that 4-(2,4-diaminophenyl)-azobenzenesulfonamide cures streptococcal infections in mice. Others will find that animals metabolize the dye to sulfanilamide. Domagk wins the 1939 Nobel Prize for the sulfa drugs, but the German government forbids him to accept. Domagk gets his medal in 1947.

1938. Pathologist Howard W. Florey and biochemist Ernst B. Chain of Oxford University evaluate Fleming's penicillin, made confident of success by the known effectiveness of the sulfa drugs. They come to the U.S. in 1941 at the outbreak of war to arrange commercial production. Fleming, Florey, and Chain share a Nobel Prize in 1945.

1939. Bacteriologist René Dubos of Rockefeller Institute for Medical Research, New York City, isolates gramicidin from soil bacterium *Bacillus brevis*. This becomes the first polypeptide antibiotic and the first antibiotic to be produced commercially, though it proves too toxic for any but external use.

1940. Stimulated by Dubos' success, Selman A. Waksman, microbiologist at Rutgers University, sifts through soil molds and isolates actinomycin. In 1942 he reports streptothricin and in 1943 streptomycin. Waksman coins the word antibiotic. Streptomycin, the first of the aminoglycosides, proves effective against gram-negative and anaerobic bacteria, whereas penicillins known to date act against only gram-positive aerobes. Waksman wins a Nobel Prize for streptomycin in 1952.

1943. Chemists William B. Stillman, A. B. Scott, and J. M. Clampit at Norwich Pharmacal Co. report nitrofurazone as the first of the nitrofuran antibacterial drugs.

1947. John Ehrlich isolates chloramphenicol from *Streptomyces venezuelae*, which is both a rare example of a nitrochloro compound in nature and a broad-spectrum antibiotic.

1948. Botanist Benjamin M. Duggar retires from the University of Wisconsin, goes to work for Lederle Laboratories, and isolates aureomycin from *S. aureofaciens*, thereby discovering the first of the tetracyclines.

1952. James McGuire of Eli Lilly isolates erythromycin from *S. erythreus*.

1957. P. Sensi of Lepetit isolates rifamycins, the first of the ansamacrolides, from *Nocardia mediterranei* in a project code-named "Rififi" after the then-popular movie and modifies one of them chemically to rifampin.

1962. Chemists George Y. Lesher and Monte D. Gruett of Sterling Drug Co. report nalidixic acid as the first of the quinolone antibacterial drugs. Donald J. Mason, Alma Dietz, and Clarence DeBoer of Upjohn isolate lincomycin, the first of the lincosaminides, from *S. lincolnensis*.

1975. Workers at Merck isolate thienamycin from *S. cattleya*, the first of the carbapenems, and develop it into Primaxin, the widest spectrum antibacterial known to date.

1980. Scientists at Squibb isolate the first of the monobactams after a massive screening of soil molds.

1986. The U.S. antibacterial drug market tops $2.5 billion, heading toward $3 billion in 1990. Medicinal chemists pursue such compounds as monobactams, carbapenems, and quinolones in vigorous efforts to outflank bacterial resistance and meet pressures to cut treatment costs.

Spiro: either extend spectrum of coverage or enhance usefulness

the infecting microbe. Previously, doctors have sometimes prescribed a combination of drugs that includes penicillin or cephalosporin and an aminoglycoside. The purpose of the aminoglycoside is to ensure that such stubborn, gram-negative bacteria as *Pseudomonas aeruginosa* are eradicated.

The nursing and pharmacy costs of using a single antibacterial are lower than those of prescribing a combination of drugs. Omitting an aminoglycoside also avoids the cost of laboratory testing for signs of kidney and hearing damage that aminoglycosides can cause. Merck prices Primaxin higher than penicillins, cephalosporins, and aminoglycosides. But the company has estimated that the total cost of a course of Primaxin is less than that of combinations.

Pfizer's cefoperazone has broad activity against gram-positive and gram-negative bacteria and can be given as a single agent twice daily, which cuts costs in comparison with other drugs or combinations given more frequently. The company also has guaranteed that if a hospital uses cefoperazone, and if the patient's hospital stay exceeds the length that medicare reimburses under DRGs, then Pfizer will replace the "extra" cefoperazone free.

The problems and opportunities of the changing U.S. antibacterial

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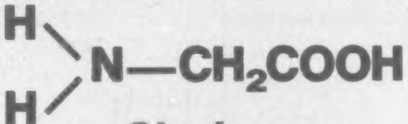

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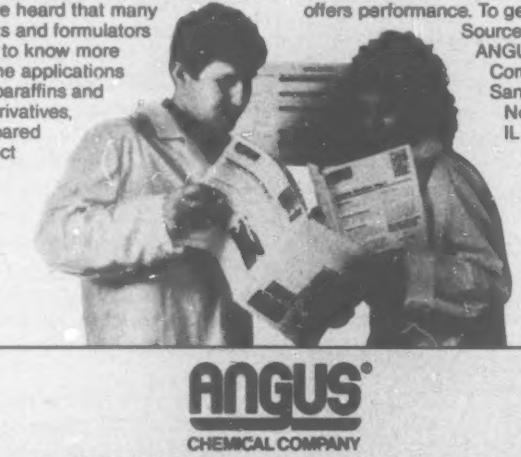

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Antibiotic plant designs emphasize sterility

To design and build antibiotic fermentation plants, drug companies often turn to such engineering firms as Catalytic, Crawford & Russell, Davy McKee, and Foster Wheeler. Largest in the field is Foster Wheeler, whose antibiotics projects under way worldwide total $500 million.

To Tele Gnudi, Foster Wheeler's technical director for pharmaceuticals and fine chemicals, the dominant theme of plant design is maintenance of sterile conditions in the face of demands for quick turnarounds of main fermentors between batches. Invading microbes can easily overwhelm antibiotic-producing molds in fermentors, causing loss of a batch and the several weeks' time to produce it.

A 10,000- to 90,000-gal batch begins in the laboratory, where workers break open a frozen vial of antibiotic-producing organism and culture it in flasks increasing in size from 250 mL to 5 L over a period of 12 days to provide an inoculum for the industrial section. They also propagate and maintain this high-productivity strain and freeze it in new vials at liquid-nitrogen temperatures.

In the industrial section of the plant, operators grow the organism for two to three days in two 100-gal seed fermentors, then for two to three days in two 1000-gal germinators, before transferring it to, for example, a 10,000-gal main fermentor. Seed fermentors and germinators are run in pairs as a backup in case something happens to one inoculum.

Assays usually show that antibiotic production has peaked after 30 days at 25 to 28 °C in the main fermentor. The mixture is cooled to 10 °C, treated with formaldehyde, and pumped over 10 to 20 minutes to a harvest tank. Other workers take a week to extract and purify the antibiotic. Meanwhile, operators of the main fermentor take 10 hours to clean it, sterilize it with 145 °C steam, and start a new batch. Molds from production batches are now unproductive mutants, so new batches must start with inoculum from the lab.

Gnudi sizes the lab and the rest of the plant around staggered scheduling of the 30-day run times of the number of main fermentors needed to achieve desired capacity. In this way, he minimizes capital investment in support equipment and maximizes use of the main fermentors. The lab must have a gowning room for workers to dress, a laundry room for gowns, a clean room to open frozen vials, and an incubator room. Avoiding architects' "standard" designs, Gnudi designs the lab and specifies furnishings after analyzing what work must be done there and what the equipment needs are.

In the industrial section, Gnudi's chief concerns in designing main fermentors are efficient operation and fast, thorough cleaning. He often specifies stainless steel, though carbon steel, copper, or glass fiber-reinforced polyester may be used. He pays careful attention to welds and polishing the interior to avoid crevices, minimizes such interior fittings as baffles and coils, leaves space to clean around and behind fittings, and installs the compressed air pipe at the bottom rather than all the way down the inside from the top.

Gnudi points out that a vertical, 30-foot-high, 20,000-gal fermentor needs a building 50 feet high and a foundation sufficient to support its weight on a 100-sq-ft area. He has sometimes reduced costs by placing fermentors horizontally in a 20-foot-high building with only their heads inside and the rest outdoors. Supporting horizontal fermentors in two places reduces the load that foundations bear. He then uses two agitators rather than one, driven by a single diesel engine. For vertical fermentors, he supports agitator motors from the floor rather than on the heads.

Another concern is sterile nutrients. These are mixtures of sugars, molasses, starch, soybean meal, cracked corn, and/or (for penicillin) corn steep liquor in water with calcium carbonate and salts. Gnudi's plants mix these in a storage tank and pass the mixture through a plate heat exchanger for heating to 121 °C with a residence time of two to four minutes. This continuously sterilized medium goes from the heat exchanger to a second storage tank from which it is fed by a metering pump to fermentors.

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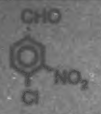
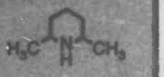
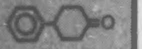


4-Chloro-3-nitrobenzaldehyde



2,6-Dimethylpiperidine, cis



4-Phenylcyclohexanone

Isosorbide dinitrate
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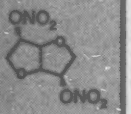
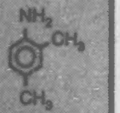
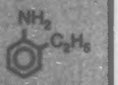
etc., USP XXI



2,4-Xylidine
and all other isomers



2-Ethylaniline
and 4-Ethylaniline



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Yet another concern is sterile air. Gnudi favors the high flow rates of centrifugal positive displacement compressors to generate this, though the 120-decibel noise level of these compressors force him to place them in separate buildings. Compressed air is chilled to condense out moisture, which might foul membranes or filters. Gnudi's clients may elect to pass moderately cooled air through a polytetrafluoroethylene membrane or thoroughly chilled and reheated air through a 0.2-μm glass filter.

They may also elect to pass anhydrous ammonia into fermentors with the air as a nitrogen source, though this requires a delicate balance of conditions to avoid outgassing of ammonia again by the air. Alternatively, ammonium phosphate salts may be added, thus controlling pH and providing nitrogen simultaneously.

For plants that produce many antibiotics, Gnudi takes care to avoid cross-contamination of products. He uses special care to isolate penicillin or cephalosporin from other production, because of the dangers of penicillin allergies. These units may be protected by scrubbers and have their own laundries.

From the main fermentor and harvest tank, the fermentation mixture goes to a rotary vacuum filter to remove the mycelium, which is the mass of filaments that molds grow. Most antibiotics are dissolved in the filtered broth, though griseofulvin is one that remains with the mycelium and must be extracted with solvents.

Depending on the antibiotic, the drug may be isolated from filtered broth by countercurrent extraction with acetone, methylisobutyl ketone, or butanol; reverse osmosis; adsorption, ion exchange, or chromatography; precipitation; or simple evaporation. The powder remaining after the final evaporation is nonsterile, technical-grade antibiotic.

This may be sold as animal feed additive or processed to sterile antibiotic for making up dosage forms. Gnudi's clients may use a sterile section of the same plant for this purpose, send the antibiotic to another location that has one, or sell it to another drug firm.

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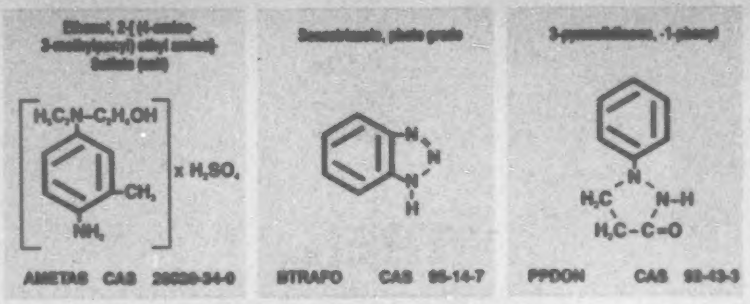
Ethanol, 2-[(4-amino-3-methylphenyl) ethyl amino]-Sulfate (salt)
H,C,N–C,H,OH
CH,
NH,
x H,SO,
AMETAS CAS 25629-34-0
Benzotriazole, photo grade
N
N
N
H
BTRAFO CAS 95-14-7
3-pyrazolidinone, -1-phenyl
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H,C
N–H
H,C–C=O
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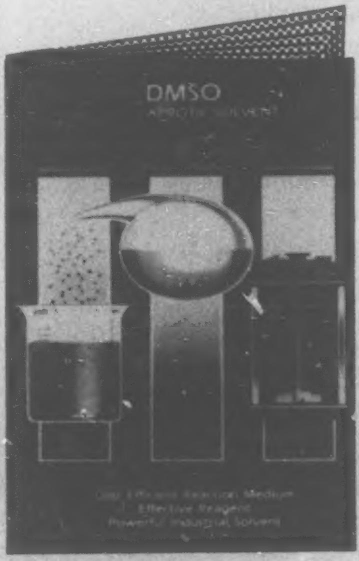

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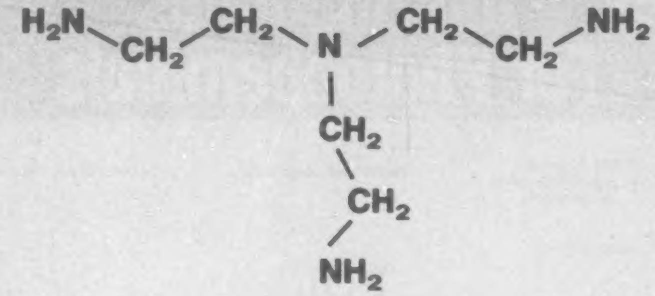

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Antibacterial drug sales to grow 5% annually

$ Millions	1985	1990
INJECTABLE ANTIBACTERIALS	**$1388**	**$1518**
Cephalosporins	765	888
First generation	207	154
Second generation	342	350
Third generation	216	384
Gram-positive drugs	180	160
Aminoglycosides	121	85
Extended-spectrum penicillins	193	185
Monobactams	0	60
Penems and carbapenems	0	95
Other	129	45
ORAL ANTIBACTERIALS	**1109**	**1509**
Cephalosporins	446	645
Tetracyclines	136	123
Erythromycins	144	162
Amoxicillin	59	75
Quinolones	0	155
Other	240	174
TOTAL	**$2497**	**$3027**

Source: Sanford C. Bernstein & Co.

market have attracted several drug companies new to antibacterials. By far the leader to date has been Eli Lilly & Co. Crossen of Bernstein & Co. estimates that Lilly's antibacterial sales in 1985 were $719 million, or almost 30% of the market.

Crossen sees great promise for Lilly's new injectable cephalosporin, ceftazidime, which may become the drug of choice for *P. aeruginosa*. He notes, however, that Glaxo and Smith Kline & French Laboratories will compete in the ceftazidime market. Lilly's sales of its older oral cephalosporin, cefaclor, also will continue well through 1990 before meeting competition from other antibacterials, Crossen says.

But such progress cannot offset market losses owing to newer antibacterials from other firms and the expiration of patents on some of Lilly's older compounds. Crossen estimates that in 1990 the company's antibacterial sales will total $596 million, still in the lead, but not quite 20% of the U.S. market.

Among companies making new efforts in antibacterials in the U.S. are Ciba-Geigy, Hoffmann-La Roche, Merrell Dow Pharmaceuticals, Ortho Pharmaceutical Corp. (subsidiary of Johnson & Johnson), Parke-Davis (division of Warner-Lambert), and Stuart Pharmaceuticals (subsidiary of ICI Americas). Crossen estimates that combined antibacterial sales of these new-entry firms could total about $290 million in 1990, which will be almost 10% of the U.S. market, compared with zero today.

In addition, Schering Corp., whose sales were limited to $9 million worth of gentamycin in 1985, may see sales of $30 million in 1990, owing to approval of an injectable β-lactam called Sch-29,482. And the quinolone amifloxicin may contribute $5 million to sales of Sterling Drug Co. in 1990. Over the past 25 years, Sterling has had minor sales of nalidixic acid, the first quinolone to be discovered..

Timothy P. Spiro, director of clinical research on metabolic and infectious diseases at Hoechst-Roussel Pharmaceuticals, Somerville, N.J., says that if a new drug is to be successful, it must either extend the spectrum of coverage or represent a scientific advance that enhances usefulness.

Hoechst-Roussel has already had considerable success with its cefotaxime injectable cephalosporin. Many doctors use it as the first line of attack for meningitis or bacteremia, for which antibiotics must be started immediately, before the organism or its antibacterial susceptibility is known.

Spiro's example of a broader-spectrum drug is cefpirome, an injectable cephalosporin that the company is putting through the U.S. approval process. Cefpirome's broader spectrum includes increased activity against difficult organisms like *P. aeruginosa*, enterococci, and methicillin-resistant staphylococci. Methicillin resistance is one hallmark of bacteria that are resistant to the newer cephalosporins also and causes concern in hospitals where such strains have begun to proliferate.

Cefpirome also resists antibiotic-inactivating β-lactamases and has a longer half-life than cefotaxime, leading Spiro to suggest the possibility of giving it only twice daily. Such a possibility would add cost savings to cefpirome's other advantages.

Roxithromycin is Spiro's example of a drug that enhances usefulness. Hoechst-Roussel is also working toward U.S. approval of this 2-methoxyethoxymethoxylimino derivative of erythromycin. The oral drug erythromycin itself has a large market in the U.S. because it is favored by pediatricians and general practitioners in office practice. It is very safe, especially among children, and attacks fungal as well as gram-positive bacterial infections.

But erythromycin is poorly absorbed in the body and can cause unpleasant gastrointestinal side effects. Spiro says that roxithromycin is much better absorbed, has a longer half-life, and has the same spectrum as erythromycin.

George B. Mackaness, president of Squibb Institute of Medical Research, has a somewhat different philosophy regarding drugs. His

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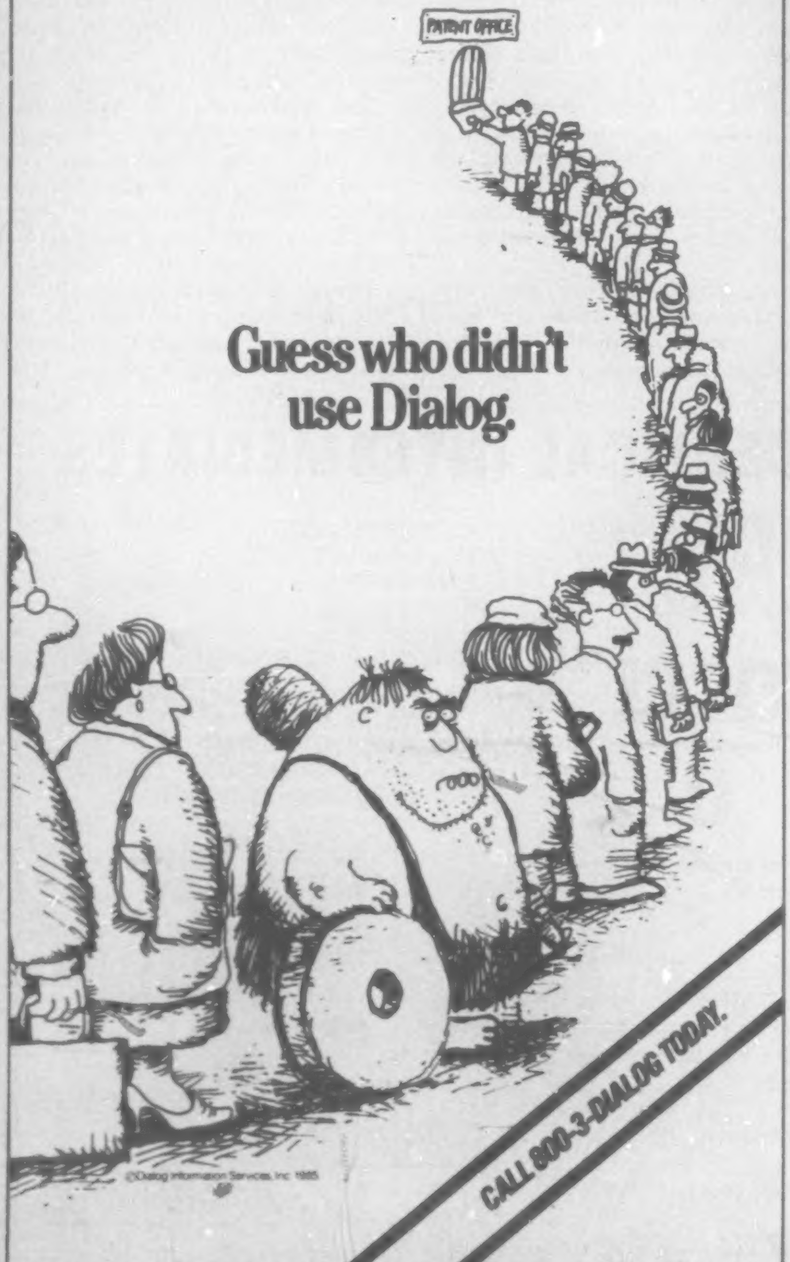

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Squibb photo

Photomicrograph of antibiotic aztreonam, tradenamed Azactam

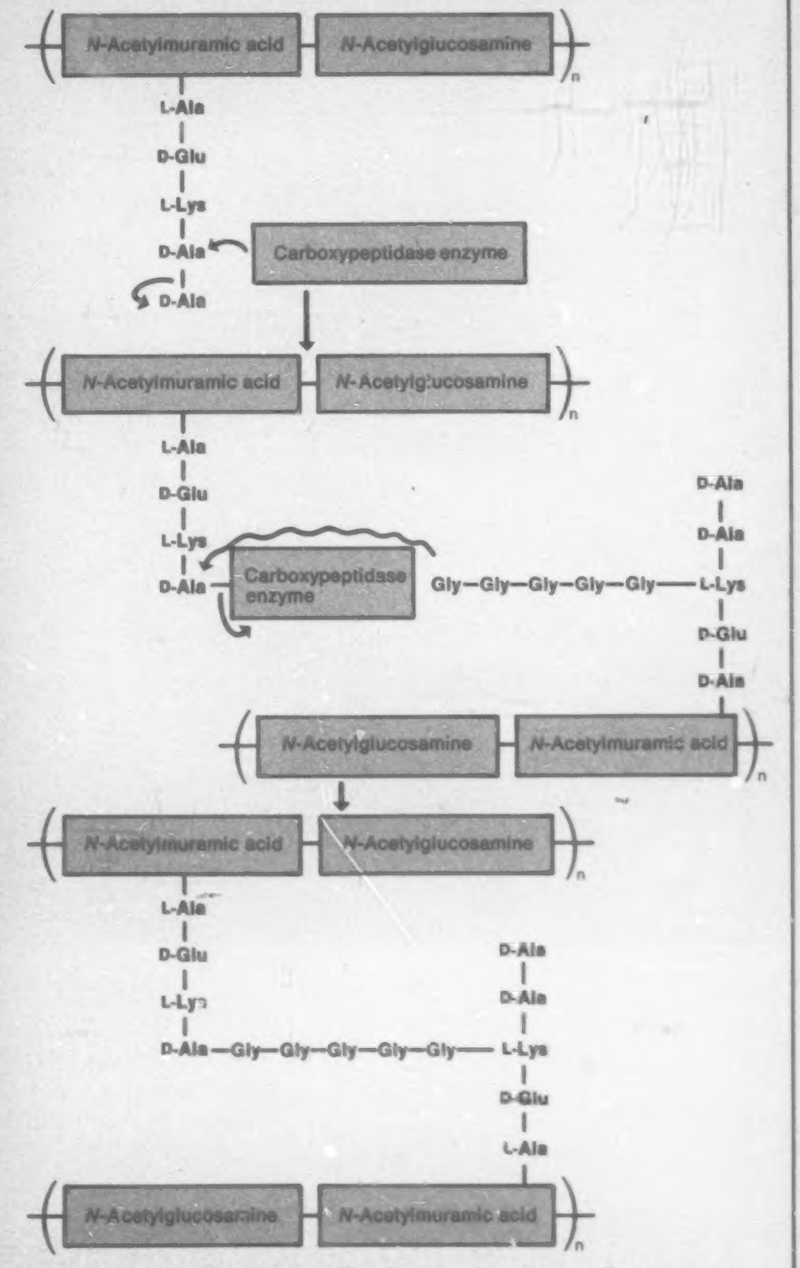
company has dissociated itself from the broad-spectrum approach to therapy and is developing aztreonam, an injectable specific against *P. aeruginosa* and other aerobic (oxygen-requiring) gram-negative bacteria. The compound is inactive against gram-positive organisms or anaerobes (those inhibited by oxygen). Further in the future is approval of tigemonam, an oral monobactam with a narrow spectrum similar to that of aztreonam. Both aztreonam and tigemonam resist β-lactamases.

"Time will establish, I think, that a more careful approach is required," says Mackaness of antibiotic therapy. He suggests that doctors may use combinations of antibiotics as a first attack on emergency infections, including aztreonam to cover gram-negative bacteria. Thus, the expense of monitoring patients for adverse reactions to aminoglycosides would be avoided. As tests come back from the laboratory, doctors can withdraw those agents from the combination that are not effective.

Mackaness' concern is that use of broad-spectrum antibiotics leads to development of bacteria in hospitals that are resistant to β-lactams generally. "Broad-spectrum antibiotics deal a broad blow to all organisms," he says. "They put all organisms under pressure to develop resistance." Patients who get broad-spectrum antibiotics in doctors' offices may later be admitted to hospitals, where they will spread resistant strains. Moreover, eliminating gram-positive bacteria may cause an overgrowth of resistant aerobic gram-negative bacteria in hospital air.

Even further in Squibb's future is a second-generation monobactam known now as SQ-83,360. The min-

Bacteria build cell walls by crosslinking peptidoglycan


N-Acetylmuramic acid
N-Acetylglucosamine
n
L-Ala
D-Glu
L-Lys
D-Ala
Carboxypeptidase enzyme
D-Ala
N-Acetylmuramic acid
N-Acetylglucosamine
n
L-Ala
D-Glu
L-Lys
D-Ala
Carboxypeptidase enzyme
D-Ala
D-Ala
Gly—Gly—Gly—Gly—Gly
L-Lys
D-Glu
D-Ala
N-Acetylglucosamine
N-Acetylmuramic acid
n
N-Acetylmuramic acid
N-Acetylglucosamine
n
L-Ala
D-Glu
L-Lys
D-Ala—Gly—Gly—Gly—Gly—Gly
D-Ala
D-Ala
L-Lys
D-Glu
L-Ala
N-Acetylglucosamine
N-Acetylmuramic acid
n

Ala = Alanine   Glu = Glutamic acid   Gly = Glycine   Lys = Lysine

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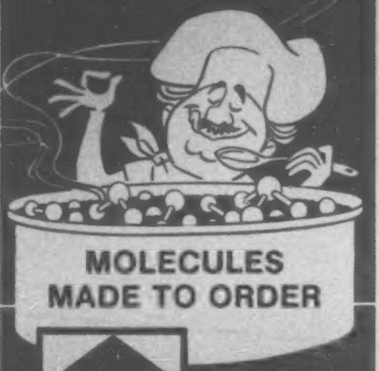
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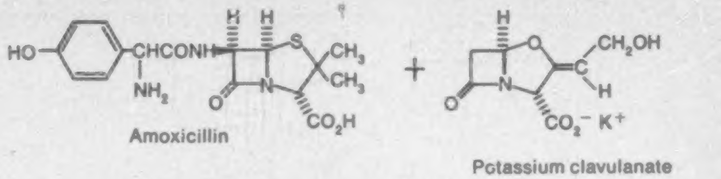
imal inhibitory concentration of this compound against *P. aeruginosa* is 0.5 μg per mL, compared with 12.5 μg per mL for aztreonam or cephalosporins. Mackaness suggests that a dihydroxypicolinoyl group on this molecule may complex iron, and thus may be absorbed by *P. aeruginosa* cells by the same route the organism uses to transport iron.

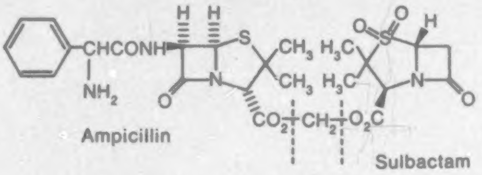
As medicinal chemists at Squibb and other firms seek to broaden (or narrow) the spectrum of antibacterials and to overcome evolving resistant bacteria, screening compounds from natural sources goes hand in hand with chemical modification of natural products. For example, Squibb scientists discovered monobactams by fermenting molds from soil samples. No living organism ever made aztreonam, the first monobactam to be commercialized. And when it goes on the market here, Squibb will produce it with totally synthetic methods.

Some firms mix β-lactamase inhibitors with antibiotics . . .



Augmentin (Beecham)

. . . but others combine inhibitors covalently



Sultamicillin (Pfizer)

Note: Augmentin is the tradename for the mixture of amoxicillin and potassium clavulanate. Sultamicillin is the generic name for covalently bonded ampicillin and sulbactam.

As far as screening for new antibiotics is concerned, there is a rough division between screening for β-lactams and for all others. One reason for this is that β-lactams have an almost unparalleled record of safety in humans. Aminoglycosides must be monitored for kidney and otic nerve toxicity. Tetracyclines stain children's teeth. Only erythromycins avoid such problems though they are effective mostly against gram-positive bacteria.

Some patients do develop aller-

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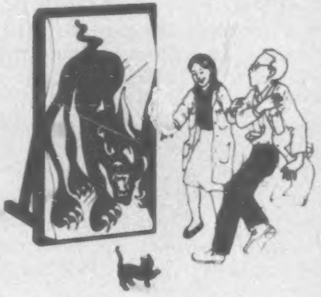

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gic hypersensitivity to β-lactams. Allergic reactions can be fatal. But even here, medicinal chemists have found β-lactams that avoid reactions in sensitive patients. And the effectiveness of penicillin G against bacterial meningitis is so great that some doctors will still give it to patients who have never had an immediate reaction to it, and then be prepared to treat a reaction.

A second reason for seeking new β-lactams specifically is that their chemistry, the molecular biology of bacterial resistance to them, and means to get around resistance have been more thoroughly worked out than for any other class. A fruitful cycle of research has evolved in which medicinal chemists' and molecular biologists' efforts have been rewarded with revealing and profitable results, leading to redoubled efforts.

One example of the desirability of β-lactams as commercial products is the saga of the development of Primaxin at Merck. Scientists there first reported isolating thienamycin from *Streptomyces cattleya* in 1976. Though thienamycin had the potential of having the broadest spectrum ever seen in an antibiotic, it was unstable.

Unwilling to give up on the compound, Merck chemists modified the basic molecule until they hit upon the *N*-formimidoyl derivative of the aminoethylthio side chain, which was stable. Further testing of this compound, called imipenem, showed that it was hydrolyzed by a human kidney enzyme called dehydropeptidase-1. This meant that imipenem could never achieve high concentrations in urine, thus rendering it useless for urinary tract infections.

Merck chemists turned to searching for an inhibitor of dehydropeptidase-1 and found one in cilastatin. A 1:1 mixture of imipenem and cilastatin produced therapeutic concentrations of imipenem in human urine.

But a physical mixture of two agents was bound to raise questions at FDA. This is because for more than 20 years the agency had traditionally judged such products "ineffective as a fixed combination." That is, Merck would have to show clinical proof that a 1:1 ratio of

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imipenem to cilastatin was not arbitrary but uniquely necessary for effectiveness. Merck scientists developed this evidence, and FDA approved the combination drug, now tradenamed Primaxin, in 1985.

In their search for new β-lactams and other antibiotic types, medicinal chemists make use of increasingly sophisticated screening methods. The screening program that uncovered the monobactams for Squibb, for example, depended on whether or not fermentation broths would stimulate bacteria to produce β-lactamases.

Squibb scientists grew cultures of *Bacillus licheniformis* on agar medium in petri dishes. This bacterium has a gene for a β-lactamase in its chromosome, but the enzyme is normally produced at very low levels. When exposed to a β-lactam, however, *B. licheniformis* responds by producing large amounts of the destroying enzyme.

The Squibb workers impregnated paper disks with fermentation broths from soil samples and laid the disks over the agar. After two to three hours of incubation, nitrocefin solution was applied to the cultures. Appearance of a red color around a disk indicated that the fermentation broth applied to that disk contained a β-lactam.

If a β-lactam was present in the fermentation broth, the *B. licheniformis* would produce large amounts of β-lactamase around that disk. The β-lactamase would hydrolyze the β-lactam group of nitrocefin, yielding the equivalent of a β-amino-*p*-styrene, whose red color would be the telltale sign.

The Squibb test was sensitive to as little as 1 ng of β-lactam, compared with 15 ng needed in bacterial growth inhibition tests and 200 to 3000 ng for tests that depend on observing changes in bacterial shape. The Squibb program yielded new β-lactams at the rate of one per 1 million tests, but the monobactams the company will bring to market as a result will more than repay the effort.

One expert in development of sophisticated, new, antibiotic screening techniques is Louis J. Nisbet. Nisbet has recently founded Xenova, a company that will offer screening services for antibiotics and compounds with other pharmacological activity. Currently, Xenova's offices are in London, but Nisbet plans permanent offices and laboratories near Oxford, England.

One such β-lactam screening method that Nisbet has developed depends on inhibiting D,D-carboxypeptidase. This enzyme cleaves a terminal D-alanine group from a pentapeptide side chain of bacterial peptidoglycan. Peptidoglycan is the sugar-peptide substance that forms bacterial cell walls. Cleavage of D-alanine from its pentapeptide side chain is the first step in reactions that crosslink peptidoglycan to form finished cell wall substance. β-Lactam antibiotics interfere with the crosslinking process, leading eventually to bursting of the bacterium.

Nisbet synthesized a uridine diphosphate/*N*-acetylmuramyl derivative of the pentapeptide as a model compound for peptidoglycan. He next isolated a D,D-carboxypeptidase from a Streptomycete mold. He added purified D,D-carboxypeptidase to a sample of fermentation broth. If the broth contained a

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Constant screening uncovers new antibiotics at Squibb

β-lactam, this would inhibit the D,D-carboxypeptidase. Then he added the pentapeptide derivative. If a β-lactam had inhibited the D,D-carboxypeptidase, the pentapeptide would not be degraded. If no β-lactam was present, then the pentapeptide would be hydrolyzed to a tetrapeptide. Nisbet analyzed for tetra- and pentapeptide with high-performance liquid chromatography.

Another screening method developed by Nisbet is for glycoprotein antibiotics of the vancomycin type. Vancomycin is important because doctors often rely on it as a second line of attack against the growing number of gram-positive bacteria like Staphylococci and Streptococci that are resistant to β-lactams. This antibiotic is also life-saving in cases of pseudomembranous colitis, a destructive irritation of the intestinal lining caused by a toxin of *Clostridium difficile*. This bacterium sometimes grows out of control after other intestinal bacteria have been killed by some antibiotics. Vancomycin destroys *C. difficile*.

Vancomycin kills bacteria by binding tightly to the D-alanyl-D-alanine group at the end of the peptidoglycan pentapeptide side chain. This action prevents crosslinking of peptidoglycan to form bacterial cell wall substance. Nisbet's screen for vancomycinlike activity uses *N,N'*-diacetyl-L-lysyl-D-alanyl-D-alanine as a model of the end of the pentapeptide side chain.

He impregnates two paper disks with the fermentation broth to be tested. He then impregnates one of

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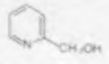
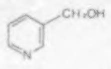
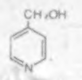


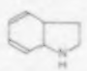
3-pyridine methanol



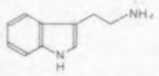
4-pyridine methanol



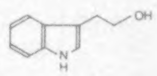
Indoline



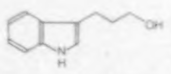
Tryptamine



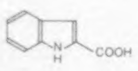
Tryptophol



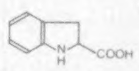
Homotryptophol



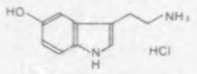
Indole-2-carboxylic acid



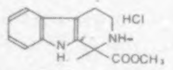
Indoline-2-carboxylic acid



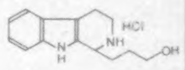
Serotonin hydrochloride



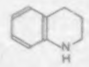
1-Methy-1-metoxycarbonyl-tetrahydro β-carboline hydrochloride



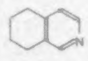
1-Hydroxypropyl-tetrahydro-β-carboline hydrochloride



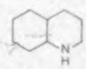
1,2,3,4-Tetrahydroquinoline



5,6,7,8-Tetrahydroisoquinoline



Decahydroquinoline



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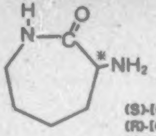

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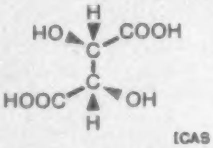
(R)-[CAS No. 28957-33-7]
(±)-[CAS No. 17929-90-7]

D(−)-Tartaric Acid



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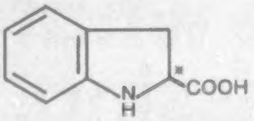
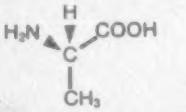


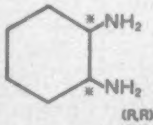
(S)-[CAS No. 79815-20-6]
(R)-[CAS No. 98167-06-7]
(±)-[CAS No. 16851-56-2]

D(−)-Alanine



[CAS No. 338-69-2]

Trans-1, 2-Diaminocyclohexane



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these disks also with the tripeptide model compound. He lays the disks over a "lawn" of bacteria on agar medium in a petri dish.

If the disk impregnated only with broth shows a zone of inhibition (a circle around the disk free of bacteria), Nisbet knows that the broth contains an antibiotic. If at the same time the disk impregnated with both broth and tripeptide shows a small or no zone of inhibition, he concludes that the antibiotic has vancomycinlike activity. This is because the tripeptide binds the antibiotic in the broth, leaving little or none to inhibit bacterial growth.

Nisbet notes that screening soil molds for vancomycin-type antibiotics turns up one new compound for every 320 tests. This compares with one compound in 10,000 to 100,000 tests using other methods. Nisbet concludes that such natural sources as molds are even richer in new antibiotics than previously suspected. Some of these compounds have value in an unmodified state. The molecular structures of others can be modified by medicinal chemists to develop even greater potency.

In addition to screening natural sources for β-lactam, vancomycin, or other known activity, microbiologists have turned recently to so-called nonclassical screening techniques. Traditionally, workers have discovered antibacterials by a shotgun approach, according to whether they produced zones of inhibition around disks. Then they study what particular antibacterials do to kill bacteria.

These studies resulted in identification of six mechanisms by which antibacterials disrupt bacterial metabolism. These six mechanisms were inhibition of biosynthesis of nucleic acids, biosynthesis of peptidoglycan, biosynthesis of lipids, functions of ribosomes (which mediate biosynthesis of proteins), functions of membranes (such as transport of certain substances in and out of bacterial cells), and metabolism of folic acid. Workers then developed screening methods to detect compounds active by one of these six classical mechanisms.

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teria. Thus, compounds that disrupt these processes are likely to be nontoxic to human cells. But other processes are also known to be unique to bacteria, and it is disruption of these to which medicinal chemists now turn to screen for new antibacterials.

For example, gram-negative bacteria surround their peptidoglycan cell walls with a membrane that consists mostly of murein lipoprotein. The antibiotic globomycin prevents conversion of an intermediate prolipoprotein to lipoprotein, causing the prolipoprotein to accumulate in the cytoplasmic membrane lying just under the cell wall, and leading eventually to bursting of the cell. Another component of the outer membrane of gram-negative bacteria is lipopolysaccharide. Chemists at Sandoz have developed a synthetic thienodiazaborine that apparently prevents conversion of D-arabinose 5-phosphate to a substance called KDO, which is a component of lipopolysaccharide.

Nonclassical screening techniques also may prove valuable for discovering compounds that are not antibacterials themselves, but potentiate the actions of antibacterials. One such class of compounds are the β-lactamase inhibitors, which include clavulanic acid, olivanic acid, and sulbactam.

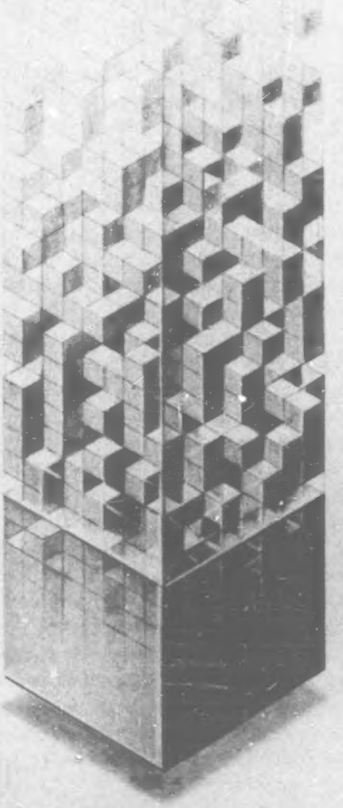
Beecham Laboratories has developed mixtures of the semisynthetic penicillins amoxicillin and ticarcillin with clavulanic acid. This development has preserved the usefulness of these workhorse penicillins against infections by bacteria that produce β-lactamases.

Moreover, β-lactamases made in large amounts by resistant bacteria may be secreted from them and form a protective umbrella for pathogens that do not produce β-lactamases themselves. Thus, combinations of β-lactams and β-lactamase inhibitors break through this protective umbrella as well as attack β-lactamase producers themselves.

Pfizer has developed mixtures of sulbactam with its new cephalosporin cefoperazone and the semisynthetic penicillin ampicillin. The company has also synthesized sultamicillin, an oral drug that is a mixed

Squibb photo

Culture of bacteria from soil examined for ability to produce antibiotics



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acetal of ampicillin and sulbactam with formaldehyde. The two ampicillin products may be approved in the U.S. in 1987.

The covalent linking of ampicillin and sulbactam makes sultamicillin a prodrug, which is transported to the infection site and hydrolyzed to the antibiotic and β-lactamase inhibitor. It may also allay the concerns of FDA about fixed combinations of drugs.

In approving Beecham's oral amoxicillin and injectable ticarcillin products, regulators at the agency may have reasoned that the products were important advances and that the two components have different, complementary functions. Some doctors caution, however, that in giving a 500-mg dose of the amoxicillin product, one 500-mg tablet should be prescribed rather than two 250-mg tablets. This is because both forms contain 125 mg of clavulanic acid, and two 250-mg tablets may deliver too much clavulanic acid.

In addition to screening natural sources for antibiotics, medicinal chemists sometimes discover classes of wholly synthetic antibacterial drugs. Examples are the sulfa drugs discovered in 1932, the nitrofurans discovered in 1943, and the quinolones discovered in 1962.

Sulfa drugs have a few important roles in modern antibacterial therapy, though they have been largely eclipsed by antibiotics. Sulfisoxazole is among drugs recommended for urinary infections. A combination of sulfamethoxazole and trimethoprim is important for certain urinary, middle ear, and bronchial infections. Sulfa drugs are thought to be mimics of *p*-aminobenzoic acid, an intermediate in bacterial folic acid synthesis. Trimethoprim is a wholly synthetic benzylpyrimidine that antagonizes folic acid.

Quinolones have received renewed attention since about 1980, owing to invention of 6-fluoro analogs that have lower incidences of side effects, reduced development of bacterial resistance, and greater bioavailability. When these new an-

Staining helps doctors plan antibiotic therapy

When doctors suspect a bacterial infection, they order cultures of sputum, blood, or spinal fluid to identify the bacteria and measure their susceptibilities to antibiotics. Testing often includes swabbing fluid onto agar, placing 12 paper disks impregnated with different antibiotics on the medium, and waiting 18 hours to see which disks have large areas clear of bacteria around them.

But for patients suspected of having such life-threatening infections as meningitis (infection of brain lining) or bacteremia (blood poisoning), antibiotics must be started at once. Cancer and transplant patients, as well as the elderly, whose immune systems are compromised, must also be treated aggressively. In such cases, doctors gain a head start both from immediate microscopic examination to determine bacterial shape and from gram staining.

For gram staining, a technician smears fluid from the patient onto a slide and dries it with quick passes over a flame. Then a stain such as gentian violet is flowed over the dried film. Next this color is fixed by flooding the film with alkaline iodine-potassium iodide solution. This is followed by a decolorizing wash with ethanol and application of a red second stain such as safranin. Bacteria that retain the initial violet stain are classed as gram-positive, whereas those that take the red counterstain are classed as gram-negative.

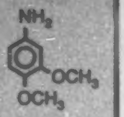
Gram-positive bacteria are surrounded by their peptidoglycan cell walls, and gram-negative organisms have a lipid layer over the peptidoglycan. Lipid outer layers stain differently from peptidoglycan and resist penetration by some antibiotics. Structures called porins in lipid layers render gram-negative bacteria susceptible to other antibiotics, however.

One variation of the gram method uses a red stain like carbol fuchsin as the first stain, ethanolic hydrochloric acid instead of ethanol as decolorizer, and methylene blue as the second stain. Such acid-fast bacteria as *Mycobacterium tuberculosis* appear red; others appear blue.

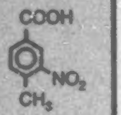
ORGANIC
INTERMEDIATES
FROM SWITZERLAND

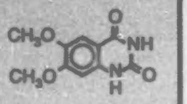
for
- pharmaceuticals
- agrochemicals
- dyestuffs
- flavors
- fragrances
- photochemicals

3,4-Dimethoxyaniline
4-Aminoveratrole

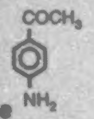


3-Nitro-p-toluic acid
and other isomers



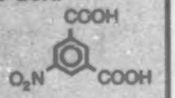


6,7-Dimethoxy-quinazoline-2,4-dione

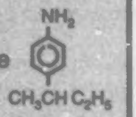


4-Aminoacetophenone

5-Nitroisophthalic acid
and derivatives



4-*sec*. Butylaniline
and 2-*sec*. Butylaniline



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alogs come to market in the U.S. beginning in 1987, they are expected to play an important role because they are oral drugs, which can be dispensed more cheaply than injectables. Their production may also be cheaper because they are made by organic synthesis rather than by fermentation and semisynthetic modification. Price competition among the half-dozen expected to be approved in the U.S. by 1990 may accelerate the passage of lower costs to patients.

Quinolones act by inhibiting DNA gyrase. This enzyme mediates the uncoiling of DNA during replication of circular bacterial chromosomes and the separation of the two circular chromosomes afterwards. Inhibiting this process is lethal in bacteria.

The first quinolones marketed in the U.S. carried a high incidence of gastrointestinal disturbances and of side effects in the central nervous system such as disturbed vision, dizziness, and seizures. The newer compounds show such side effects in less than 5% of patients. Concern continues about mediation of cartilage erosion by even the newer quinolones in very young laboratory animals. Because of this concern, they will be contraindicated for children.

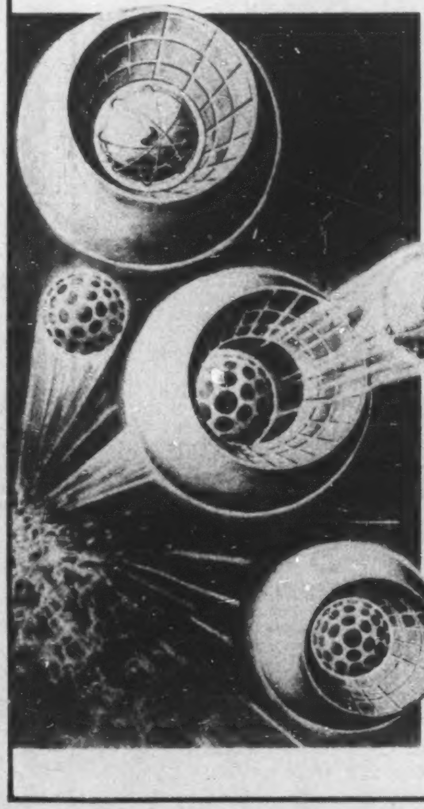
A second disadvantage of the early quinolones was that they were poorly absorbed in the bloodstream. They did achieve high concentrations in urine, however, leading to their use in urinary infections. Absorption of the newer compounds is much better.

Third, patient-infecting bacteria tended to develop resistance to early quinolones quickly. Some workers have suggested that bacteria were able to modify their cell walls or membranes in such a way as to shut out the quinolone molecules. The 6-fluoro derivatives show much slower development of resistance.

Although the virtue of the quinolones is that they are broad-spectrum oral drugs, some doctors would like to see injectables developed. This is because patients do not eat or drink for a few days after surgery, and anesthetics render their digestive systems inactive. Others may have gastrointestinal disease and be unable to tolerate oral drugs.

Pefloxacin is a quinolone that has had some success as an injectable as well as an oral drug in France. No company is thought to be developing the drug for the U.S. market, however.

Security analyst Vietor at Merrill Lynch estimates that Merck will be first in the U.S. market with norfloxacin among the new generation quinolones, followed by the enoxacin of Parke-Davis. Miles Laboratories may or may not get approval for ciprofloxacin before Ortho does for ofloxacin. Both ciprofloxacin and ofloxacin have very broad spectra and could become important antibacterials in the U.S., even if the two other compounds are introduced first. □



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Mole for mole, Lithco's LDA is less costly than *n*-butyllithium. It contains 35% less hydrocarbon solvent than LDA made *in situ* via the *n*-butyllithium process, allowing greater reactor through-put. Also, Lithco's LDA reduces total process cost by eliminating many steps required in most alternate processes. And . . . it's available in bulk quantities.

From its new production facility in North Carolina, Lithco can produce a variety of lithium dialkylamides, including lithium *bis*(trimethylsilyl)amide. Long a leader in the manufacture of lithium products, Lithco is now becoming a pacesetter in the custom synthesis of organometallic specialties.

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OCTOBER 6, 1986

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Textile imports hurting fiber intermediates

A Key Chemicals Review
Page 11

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CHEMICAL & ENGINEERING NEWS

OCTOBER 6, 1986

News of the Week

- **Tax Reform Act of 1986 means drastically lower rates but fewer allowable deductions. Page 4**
- **Animal-rights group Ark II charges Gillette Co. with abuse of laboratory animals. Page 5**
- **New software makes it possible to develop foam parts in half the time previously required. Page 5**
- **EPA issues an immediate ban on insecticide dicofol produced by Rohm & Haas. Page 6**
- **Oncor offers blood test that uses a radioactive label to detect AIDS virus. Page 6**

Cover: Robot at Du Pont's Seaford, Del., plant packs nylon fiber for shipment

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The Department
Newscripts 52

International Business

Strong yen is adversely affecting Japan's chemical firms; exports are less competitive and economy is slowing down. **Page 16**

Government

Pesticide bill clears House easily but now faces difficulties in Senate because of some controversial amendments adopted by House. **Page 19**

Science

Investigations of inorganic and organometallic complexes that show promise as antitumor agents intensify. **Page 21**

Use of nonlinear optical effects at solid-liquid interfaces may improve understanding of events at surfaces of operating electrodes. **Page 22**

New low-cost compound and reaction database program that runs on a microcomputer is geared to small labs. **Page 24**

Applying principles of surface chemistry to the study of nerves may advance understanding of nerve function. **Page 26**

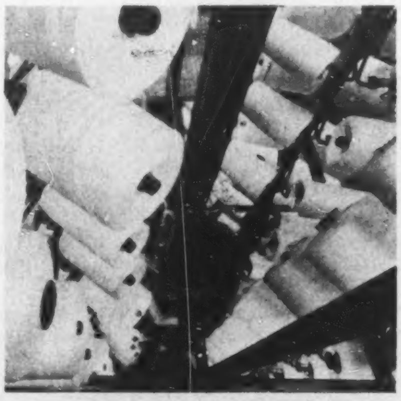
Research on action of human plasma at membrane surfaces leads to protein adsorption/desorption hypothesis. **Page 27**

Education

Chemistry laboratory adapted for blind students by multidisciplinary team at University of Louisville. **Page 28**

Awards

ACS award winners: Angyal, Arcos, Bartok, Battista, Berson, Beynon, Drickamer, Hall, and Heine. **Page 33**



Business

Growth of fiber intermediates DMT/PTA and cyclohexane is hampered by apparel imports and slowed exports. Production of ethylene oxide is likely to decrease because of decline in demand. Page 11

Fiber Intermediates Demand Dampened by Apparel Imports

Little growth in U.S. output of major intermediates DMT/PTA and cyclohexane expected this year; ethylene oxide production may decline

Bruce F. Greek, C&EN Houston

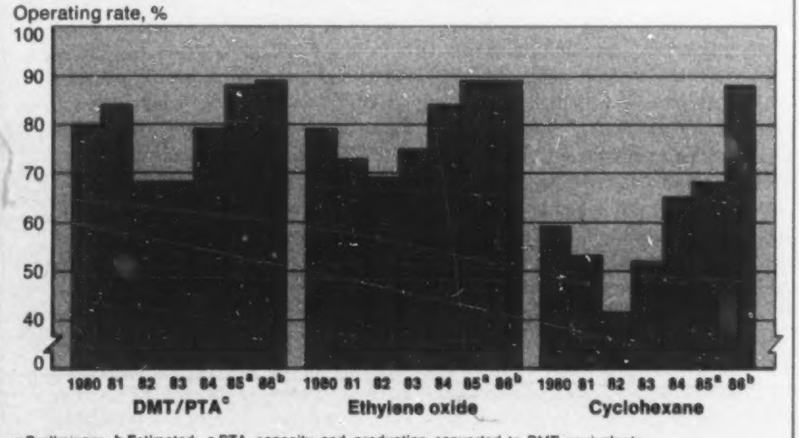
Imports of apparel made with polyester and nylon fibers continue to limit U.S. production of textiles of the same fibers and thus are dampening growth in U.S. production of those fibers and the intermediates used to make them. More dimethyl terephthalate (DMT), purified terephthalic acid (PTA), and cyclohexane will be produced this year because of increased demand for exports and inventory building, but not because of higher production of synthetic fibers.

Production of the other major fiber intermediate—ethylene oxide—likely will decrease because the decline in its demand for making polyesters will more than offset any small growth in its demand for making antifreeze. Ethylene oxide is used to make fiber-grade ethylene glycol; ethylene glycol together with DMT/PTA gives polyester—poly(ethylene glycol terephthalate) (PET).

Unless apparel imports can be held at current levels, the outlook for growth in production of DMT/PTA, cyclohexane, and ethylene oxide is uncertain. But even if apparel imports level off, DMT/PTA and ethylene oxide production probably will fall. A decline in polyester consumption also could result from increased use of cotton in apparel, either alone or blended with polyester fiber, because prices for cotton are low as a result of efforts to spur exports and use up U.S. cotton supplies.

Key Chemicals

Operating rates have pushed close to 90%



a Preliminary. b Estimated. c PTA capacity and production converted to DMT equivalents.
Sources: International Trade Commission, C&EN estimates

Exports of DMT/PTA now are growing less rapidly and are expected to decline as capacity to make the polyester intermediates grows in Asia. Polyester fiber exports could decline faster than U.S. uses grow, if apparel imports are limited to allow normal growth in U.S. consumption of polyester fibers. It is more likely, however, that apparel imports will rise despite various efforts to limit them and that exports of DMT/PTA will decline in the late 1980s.

Growth in polyester bottle resins could partly offset the effect on DMT/PTA of imported apparel and decline in exports. Demand for these resins has risen at rates below some of the very rosy forecasts, but still at good rates.

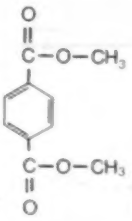
Most of these resins are of the PET type, which pulls ethylene oxide along as well. Forecasts for bottle resins continue to call for 10 to 25% year-to-year growth rates and substantial volume growth. Many of those forecasts also have a proviso that if technological developments lead to hot-fill capability, better vapor barriers, and other improvements in volume-produced bottles and other containers, then growth in demand could be even higher.

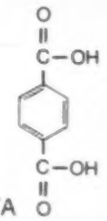
Other polyester resins (especially the butylene form) are being developed by several companies to be made into a host of fabricated products other than containers. These engineering resins, and nylon engineering resins as well, could further make up for declines in demand for DMT/PTA and cyclohexane because of slipping U.S. fiber demand.

For some details of the near-term outlook for these major-volume fiber intermediates, please see the following pages.

Key Chemicals

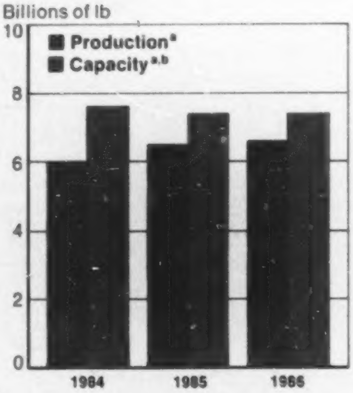
DMT/PTA


DMT


PTA

- ***Demand stronger***
- ***Capacity on hold***
- ***Prices off slightly***

PRODUCTION/CAPACITY



a DMT and DMT equivalents of PTA (1.0 lb of PTA = 1.17 lb of DMT). b First quarter.

MAJOR PRODUCERS

Amoco Chemical, Cape Industries, Du Pont, Eastman Chemical

HOW MADE

Oxidation of p-*xylene to make PTA; oxidation of* p-*xylene and concurrent esterification with methanol to make DMT*

MAJOR DERIVATIVES

Poly(ethylene terephthalate) 90%, poly(butylene terephthalate) 5%

MAJOR END USES

Polyester fibers 65%, bottles 15%, films 15%, engineering resins 5%

FOREIGN TRADE

Exports—rising to more than 1.3 billion lb, imports—negligible

PRICES

About 26 cents per lb for DMT and 28 cents per lb for PTA

Strong exports of dimethyl terephthalate (DMT) and purified terephthalic acid (PTA) in 1986 likely will boost production of those polyester materials despite a lackluster performance by polyester fibers, their major use. Other applications of DMT and PTA—polyester bottles, films, and engineering resins—will add to growth this year. Of these, bottles is the largest use, but they account for only about 15% of total DMT/PTA consumption.

As the third quarter ends, estimates of DMT/PTA total production for this year cluster around 6.6 billion lb, up less than 200 million lb from estimated 1985 output. (Estimates are based on DMT production plus PTA production converted to DMT equivalents in the ratio 1.17 to 1.) Forecasts for increased output are based on exports holding up in the fourth quarter, or increasing slightly, and polyester fiber consumption remaining at about the same level as earlier this year, down 2 to 3% from 1985. Demand for bottle resin, expected to rise 10 to 15% during 1986, will contribute to the higher output of DMT/PTA by requiring as much as 100 million lb more material than it did last year.

Capacity to make DMT/PTA remains on hold at 7.4 billion lb. That includes PTA converted to DMT equivalents. Because of scrapping of a previously mothballed plant, however, capacity is lower than two years ago. Other than minor debottlenecking work, no capacity expansions are in the works. Consequently, if 1986 production of DMT/PTA totals 6.6 billion lb, U.S. capacity will be run at an average rate of 89% of nameplate, which is definitely higher than in recent years.

Nevertheless, this higher rate remains below a level necessary to create a tight supply in the polyester industry. It also remains low enough that prices have weakened during 1986. Part of that slack stems from consumers' expectation of a pass-through of the lower feedstock costs of *p*-xylene and methanol. Declines in demand for polyester fibers among U.S. textile makers also are responsible. The declines result from increased imports of apparel containing polyester fiber and from a shift toward higher use of cotton in blends with polyester because of a large drop in cotton prices.

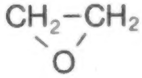
Exports of DMT/PTA, at more than 20% of U.S. output, will rise less than they did last year. Exports this year could reach 1.4 billion lb, up from about 1.3 billion lb in 1985 and less than 900 million lb in 1984. However, 1986 may be the last year for a gain in exports and higher U.S. production of DMT/PTA, because of worldwide capacity expansions, especially in the Pacific Rim nations.

DMT/PTA consumption in the U.S. is about 5.2 billion lb. Roughly two thirds (or 3.4 billion lb) eventually end up in a fabricated product containing polyester fiber. The apparel market, which continues to be battered by imports, takes the largest share of polyester fibers. Home furnishings are next in size and also are affected by imported finished products, although to a lesser degree than the apparel market. Industrial uses of polyester fibers are varied. Tire cord is a major part of the market, although that use has been reduced by use of other fibers in longer-lasting radial tires, the trend toward smaller-sized tires, and growing imports of replacement tires.

Because demand for bottle resins and other packaging forms is growing both in the U.S. and for export, those resins continue to be the bright spot for DMT/PTA. Capacity expansions for these resins are under way by several producers, and demand for DMT/PTA in packaging uses could reach 800 million lb this year.

The other significant polyester end uses of DMT/PTA are film and molding resins. Most film resins are the ethylene form, and most molding or engineering resins are the butylene form. Together the resins could require 1 billion lb of DMT/PTA this year, as a result of about 5% growth.

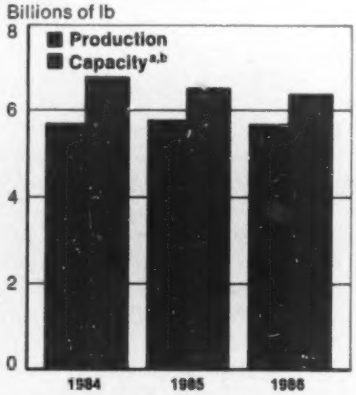
Key Chemicals



Ethylene oxide

- ***Demand weak***
- ***Capacity lower***
- ***Prices down***

PRODUCTION/CAPACITY



a First quarter. b Some capacity reported mothballed not included.

MAJOR PRODUCERS

BASF Wyandotte, ICI Americas, Shell Chemical, Texaco Chemical, Union Carbide

HOW MADE

Vapor-phase oxidation of ethylene with oxygen

MAJOR DERIVATIVES

Ethylene glycol 60%; ethoxylates 10%; ethanolamines 10%; di-, tri-, and polyethylene glycols 10%

MAJOR END USES

Polyester fibers, films, and molded items 25%; antifreeze 30%; surfactants 15%; solvents 15%

FOREIGN TRADE

Exports—tiny, falling to less than 25 million lb; imports—negligible

PRICE

About 25 cents per lb (merchant sales are only 10% of production)

Growth in ethylene oxide production is stymied by imports of apparel containing polyester fibers and by lack of growth in demand for antifreeze. Ethylene oxide's major derivative—glycol—is a key ingredient in polyester fibers and antifreeze. Glycol consumes more than 60% of U.S. ethylene oxide output, reflecting the significance of these uses to the outlook for ethylene oxide. Other uses for ethylene oxide aren't seriously affected by imported end products. Those uses, however, are growing slowly and will affect ethylene oxide growth only modestly.

The weak growth in the dominant uses of ethylene oxide will hold production stagnant at 5.7 billion to 5.8 billion lb again this year, down slightly from the peak 5.83 billion lb produced in 1985, according to preliminary estimates. Output last peaked in 1979 when it was slightly less than 5.7 billion lb. In the early 1980s, production slipped to less than 5 billion lb and did not rise again until 1983.

U.S. ethylene oxide capacity peaked in 1983 at nearly 7.3 billion lb and has fallen since then to about 6.4 billion lb, excluding some capacity not expected to be used again. Prospects for capacity expansions, other than minor debottlenecking, are slim because of the current overcapacity and the outlook for slow growth in the various end uses. With prospects for a small decline in output this year, nameplate capacity will be operated at a rate of about 89%. That rate is higher than in recent years because of shutdowns of capacity.

Because exports are small relative to total production, nearly all ethylene oxide produced is consumed in U.S. end-use markets. The net of exports over imports of ethylene glycol, however, provides the equivalent of exporting some 200 million lb of ethylene oxide. Other derivatives of ethylene oxide (such as ethanolamines) have net exports and provide additional export equivalents. Nevertheless, derivatives going to export account for only 5 to 10% of ethylene oxide consumption.

Less than 10% of ethylene oxide production is sold. Nearly all producers use it captively to make various derivatives. They do sell some ethylene oxide when their needs for use in derivatives are below incremental production.

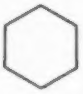
More than 90% of the glycol made from ethylene oxide goes to two uses, antifreeze and polyester resins. The split between those two markets currently is about 50-50. If bottle resins continue to give a boost to polyesters as they have during the past few years, polyesters will become the largest use of ethylene glycol and, in turn, of ethylene oxide.

Changes in automobile and truck sizes have slowed growth in antifreeze demand during the past decade. Cars with smaller engines substantially reduce antifreeze initial-fill volumes. Moreover, rapid growth in sales of imported cars during the beginning of this decade further reduced initial-fill demand.

Antifreeze replacement demand also has fallen off because of the smaller-sized radiators. Outlook for the antifreeze market for ethylene oxide remains one of low growth, at about 1% annually for the remainder of this decade.

Other glycols account for less than 10% of ethylene oxide use. They go into a variety of end uses, such as intermediates for some specialty chemicals and solvents. Because of their varied end uses, growth is difficult to forecast but probably will be 2 to 4% annually.

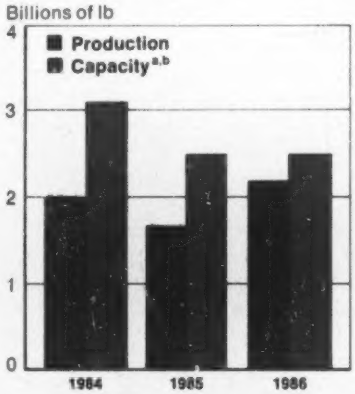
Ethanolamines, various ethoxylates, and glycol ethers account for most of the remaining consumption of ethylene oxide. Those are largely intermediates for various end products used as detergents, solvents, and power transmission fluids. Demand for ethylene oxide in those uses also is forecast to grow 2 to 4% annually.



Cyclohexane

- ***Output recovering***
- ***Capacity varying***
- ***Prices unstable***

PRODUCTION/CAPACITY



[a] First quarter. [b] Some capacity shut down and may not be restarted.

MAJOR PRODUCERS

Chevron, Phillips, Sun, Texaco, Unocal, Champlin

HOW MADE

Catalytic hydrogenation of benzene; recovered from natural gasoline

MAJOR DERIVATIVES

Adipic acid 60%, caprolactam 30%

MAJOR END USES

Nylon 66 60%, nylon 6 30%

FOREIGN TRADE

Exports—rising to near 300 million lb, imports—holding at less than 10 million lb

PRICE

About 90 cents per gal

Cyclohexane supply has become tighter for consumers of this nylon intermediate. Operating capacity to make cyclohexane has declined, reducing output as demand for nylon fibers enters a seasonal upturn. Cyclohexane prices likely will rise with the tightening supply, but it is uncertain whether they will rise more than expected from the increased price of benzene, which along with hydrogen is the basic raw material for cyclohexane.

Production of cyclohexane will rise substantially this year to about 2.2 billion lb from 1.7 billion lb in 1985. All of the 1986 production may not be used. Some of it likely will go into inventories drawn down during 1985. Growing exports are expected to take 50 million to 100 million lb more than the 228 million lb exported in 1985.

Capacity to make cyclohexane (mainly by hydrogenation of benzene) totaled about 2.5 billion lb at the beginning of this year. During the third quarter, Du Pont stopped production because the company had shut down the chlorine-caustic soda unit adjacent to its cyclohexane unit at Corpus Christi, Tex., and no longer had a supply of hydrogen. That cyclohexane unit has a nameplate capacity of about 325 million lb per year. Earlier this year, Chevron shuttered a smaller cyclohexane unit at Port Arthur, Tex. However, in June, the Chevron plant was restarted and continues to operate. Units of Phillips 66, which recover cyclohexane from natural gasoline, are run at varying production rates depending on the quantity of cyclohexane in gasoline fed to the plants. The North American cyclohexane supply also has been reduced by the shutdown of a plant in Canada.

If cyclohexane output totals 2.2 billion lb during 1986, the nameplate operable capacity will be run at an average of 88%. However, if nearly 200 million lb of 1986 capacity is removed from the nameplate total because of the unusually lengthy shutdowns, then the operating rate will jump to more than 95%. That level of operation is about full out because cyclohexane units are noted for frequent, brief shutdowns because of minor operating problems.

Current operating rates provide a better climate for producers than the one five years ago when rates ranged from 50 to 60% of nameplate capacity. Those low rates and very competitive pricing led some producers to leave the business during the early 1980s.

High operating rates depend mainly on the nylon business and, to a lesser degree, on exports. Cyclohexane has few uses other than as an intermediate for making adipic acid for nylon 66 or caprolactam for nylon 6. The main nonnylon uses are as a solvent or in making cyclohexanone (also used as a solvent) and account for less than 5% of U.S. consumption. None of those solvent or other minor uses are growing much and will have minimal impact on cyclohexane demand this year.

The use of cyclohexane in nylon divides about 2 to 1 between nylon 66 and nylon 6. About 10% of adipic acid production goes to make other products, such as specialty polyurethanes and plasticizers for polyvinyl chloride, as well as several small-volume miscellaneous chemicals. A small amount (less than 2%) of caprolactam is used in miscellaneous products. None of those nonnylon uses are growing much and will not have any significant effect on demand for cyclohexane in 1986.

Nylon fiber production inched up during the early part of this year as producers kept tight reins on inventory growth. Apparel use of nylon fibers is being hit by imports of finished products, but carpet use remains relatively immune from the effects of imports. Rising home sales during the first half of this year have helped nylon carpet sales and, in turn, nylon production. A larger share of nylon 6 goes into carpets than does nylon 66. Hence this nylon form is even less affected by imports of finished nylon products.

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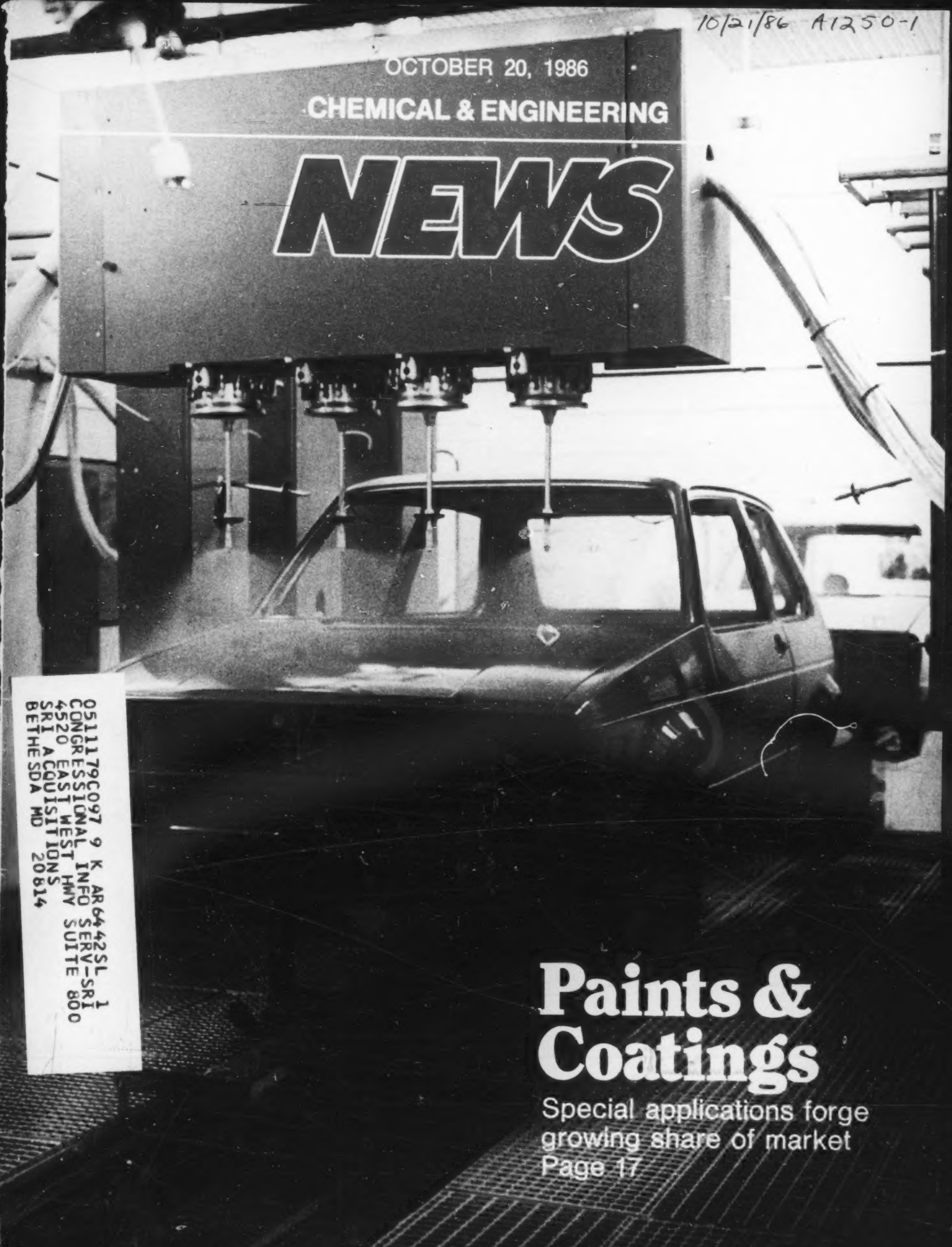
OCTOBER 20, 1986

CHEMICAL & ENGINEERING NEWS



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Paints & Coatings

Special applications forge growing share of market

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CHEMICAL & ENGINEERING
NEWS

Volume 64, Number 42
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OCTOBER 20, 1986

News of the Week

- **Nobel Prize winners in chemistry, physics, and physiology or medicine are announced.** Page 4
- **Initiative on California ballots is designed to limit salaries of state employees, which would have a harmful effect on University of California's system of higher education.** Page 5
- **U.S. chemical advisers must take a tough stand in multinational trade negotiations to halt erosion of chemical trade surplus.** Page 6
- **USX, in the midst of a takeover battle with corporate raider Carl Icahn, plans to spin off its chemical operations into a separate company, Aristech Chemical Corp.** Page 6

Government

Competitive challenge from Japan is being dealt with in an indifferent and inconsistent manner by White House, according to critics. Page 11

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Outlook for chemical engineering is bleak as the level of research opportunities is reduced by changes in industry. Page 14

Temperature-adaptable fabrics that have enhanced thermal storage and release properties are being developed by USDA. Page 15

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Chiral hydroboration technique is extended to synthesis of primary amines of essentially 100% optical purity. Page 16

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Petroleum Research Fund provides grants-in-aid for advanced scientific education and fundamental research in "the petroleum field." Page 60

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Special applications are capturing a growing share of the paint market, which is expected to reach a record $10 billion this year. Page 17

Cover: Photo courtesy of BASF

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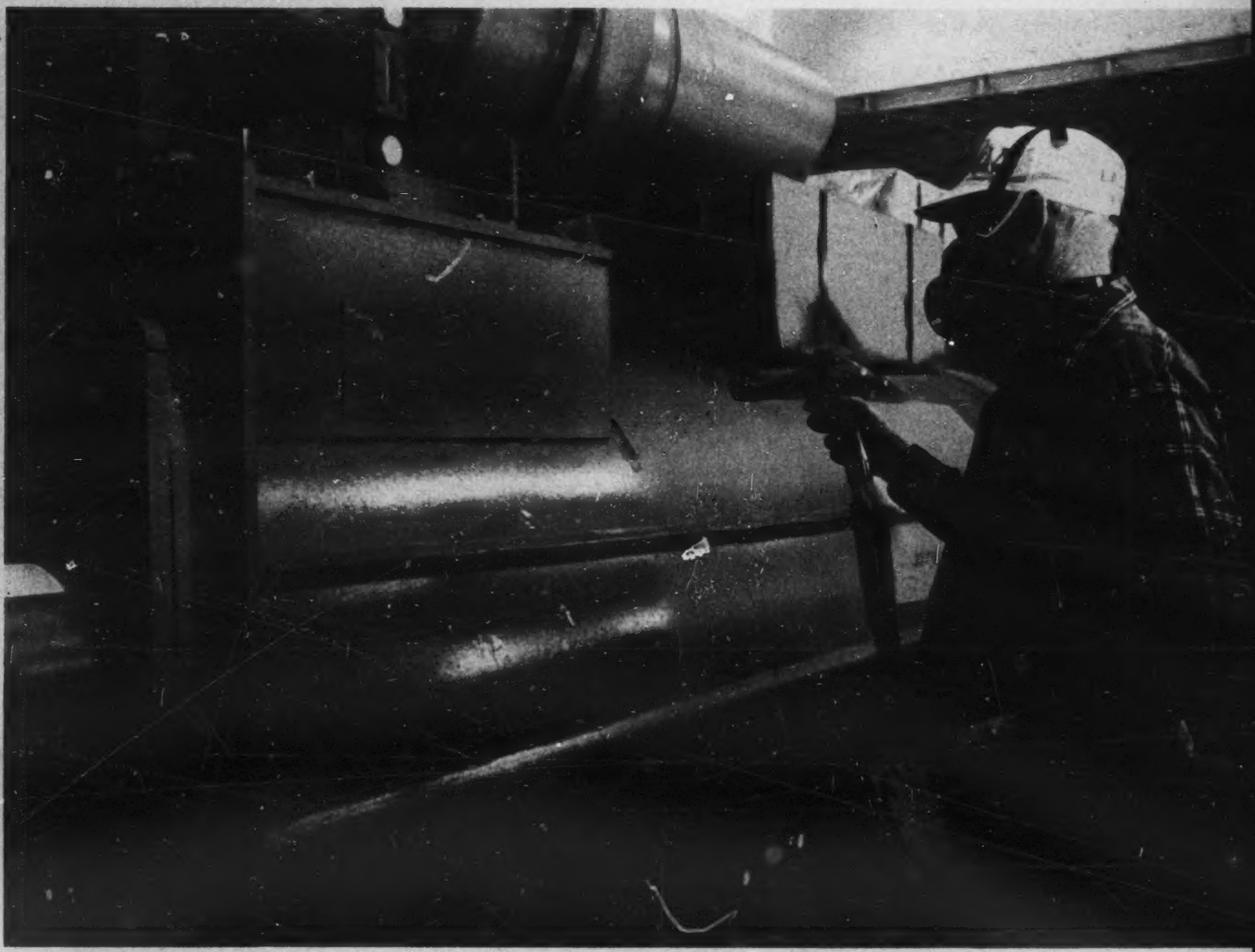


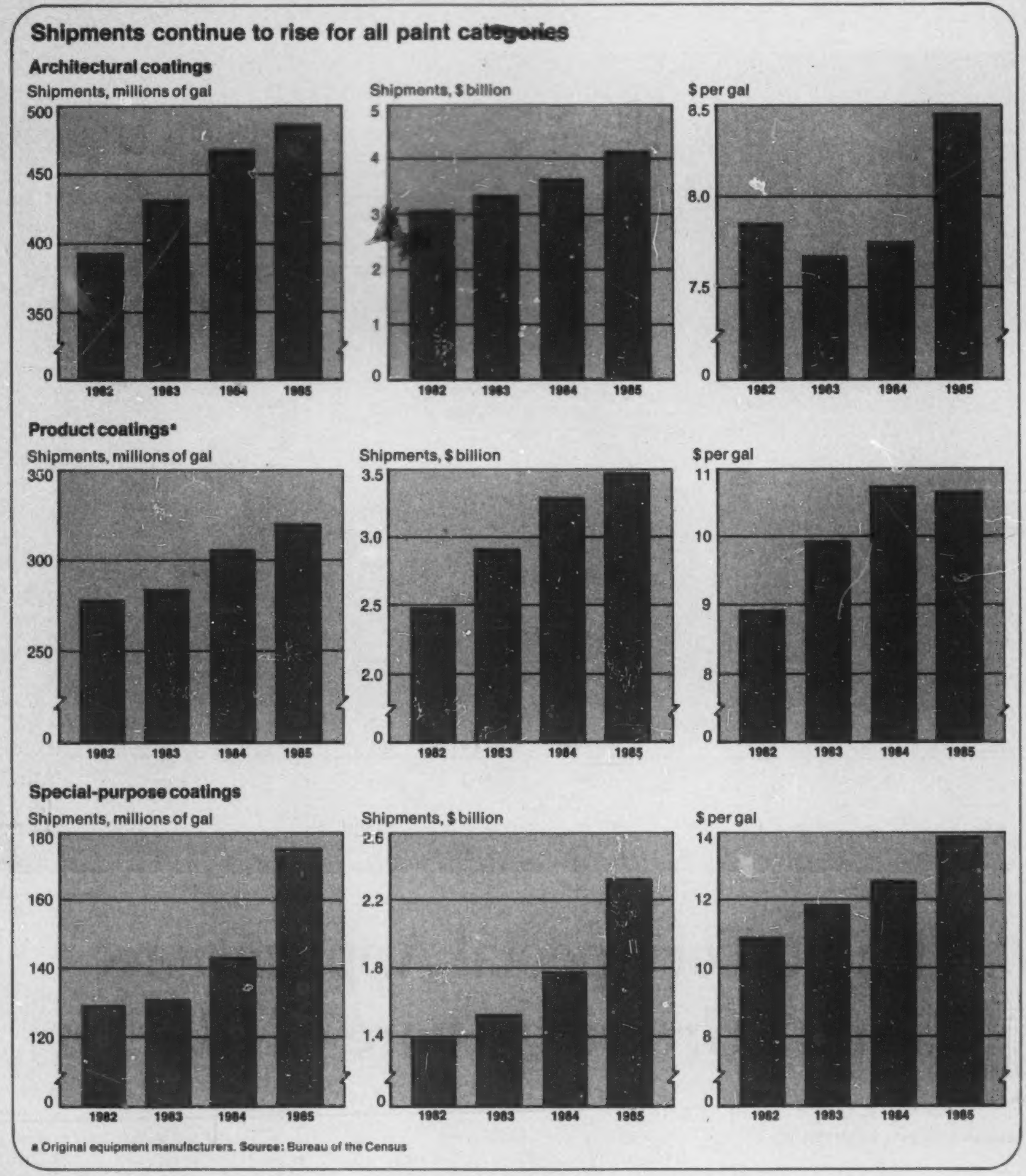
Dow Chemical photo

Paints for Special Applications Capture Growing Share of Market

William J. Storck, C&EN New York

The paint industry in the past few years has been in a state of flux. Consolidation, specialization, internationalization, and service are words frequently heard around the industry today—an industry that also has been described as mature and lackluster.

Companies such as the U.K.'s Imperial Chemical Industries and West Germany's BASF are beefing up their U.S. operations by purchasing big paint companies here. Other large firms are buying up smaller ones, reducing the large number of U.S. paint producers. Companies such as Du Pont are selling off unwanted parts of their paint businesses and buying other businesses to supplement paint operations that they still consider attractive. The latest of these is DeSoto, which last month disclosed that it will sell its automobile coatings business, among others. Richard R. Missar, chairman, president, and chief executive officer of DeSoto, says, "The decision to restructure will allow DeSoto to concentrate its resources on those key consumer paint, industrial coatings, specialty chemical, and deter-



Shipments continue to rise for all paint categories

a Original equipment manufacturers. Source: Bureau of the Census

gent businesses that generate a more attractive return on investment."

As paint operations become more sophisticated, both paint makers and firms that produce raw materials for paint are finding that they must support their sales efforts with technical services. This is all against a backdrop of a highly cyclical industry, tied largely to big-ticket items such as houses and automobiles.

The paint industry is made up of three main categories: architectural coatings, product coatings sold to original equipment manufacturers (OEM), and special-purpose coatings. Architectural coatings, which include both interior and exterior house paint, make up almost half the paint volume sold in the U.S. Product coatings for OEM include automotive and appliance coatings as their big-volume contributors and account for about 33% of U.S. paint

Prospects brighten for titanium dioxide producers

Producers of titanium dioxide, the largest-volume paint pigment, are having a great year. Pressed by increased demand from the paint and other industries, supplies of the pigment are relatively tight and prices are firm. Suppliers worldwide are pushing to meet demand.

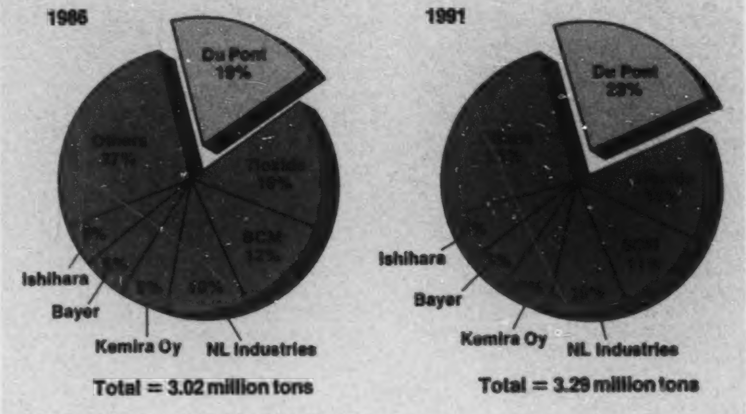
Prospects for titanium dioxide have not always been this rosy. According to Donald V. Borst, president of Hanson Industries USA's SCM pigments division, overcapacity, depressed prices, and environmental pressures during the late 1970s and early 1980s resulted in plant closures, a halt to new plant construction, and significant industry consolidation.

Borst told the meeting of the World Chemical Congress of Marketing & Business Research held in Newport Beach, Calif., last month that today supply and demand are just about in balance and this, coupled with significant increases in titaniferous raw material costs, has resulted in increased prices for titanium dioxide in the marketplace.

But, he says, the supply situation could be much worse if producers had not had faith in the industry. SCM, for example, has acquired four titanium dioxide plants since 1983. Other titanium dioxide producers such as Du Pont and Kerr-McGee have been increasing the productivity of their plants.

Borst says that historically the titanium dioxide industry has operated at an aggregate effective capacity well below its rated capacity. Reasons include shutdowns for maintenance and production-grade changes, operating limitations for environmental protection, and overstatement of nameplate capacity.

Dupont will increase TiO_2 capacity lead in next five years



Total = 3.02 million tons

Total = 3.29 million tons

Source: SCM pigments division, Hanson Industries USA

The rate of price increases for titanium dioxide will moderate, according to Borst. With the current high profit levels being enjoyed by titanium dioxide producers, he says, further price increases are likely to be a reflection of general inflation and the increasing cost of raw materials and environmental protection.

According to Borst, as demand has increased and supplies have tightened, profit margins have improved, justifying incremental expansions of existing plants. They also have led to technological changes and more recently to the announcement of new plants, apparently on the assumption that future prices will reach reinvestment levels, he says.

At least nine new plants to be completed over the next four to five years have been announced, with a total capacity of more than 400,000 tons. This is equal to 15% of 1985 total world consumption in an industry that is growing at only 2 to 2.5% per year. And the new plants will bring worldwide rated capacity to almost 3.3 million tons per year from the current level of 3.0 million tons.

It is interesting, Borst says, that all of the new plants will be based on the chloride process, whereas 63% of current world capacity is based on the sulfate process. A study of the titanium dioxide industry by Charles Kline & Co., the Fairfield, N.J., consulting firm, does not find this process change surprising. Kline says that stricter worldwide environmental regulations are causing manufacturing changes, including switching to the chloride process. Not only will the new plants use the chloride process, but some existing sulfate plants will be switched over. By 1990, 44% of total world production will be by the chloride process, compared with 37% in 1985.

volume. Special-purpose coatings, at almost 18% of U.S. paint volume, include automotive refinishing and a number of large-volume maintenance items. All of these categories contain some smaller-volume uses, but the big-ticket, highly cyclical items dominate.

The past few post-recession years have been fairly good to the paint industry. Total shipments of paints and coatings grew 6.9% in 1984, compared to 1983, to 917 million gal, according to the Commerce Department. The value of shipments increased 11.6% to $8.69 billion. In 1985, shipments increase 7.1% to 982 million gal and the value of those shipments climbed 14.3% to $9.92 billion.

In 1986 growth is likely to continue, but at a slower rate than in the past two years as the economy slows down. Through the first half of this year, Commerce Department figures show paint and coatings shipments up 3.8% from the corresponding period in 1985 to 522 million gal, while the value of those shipments has increased 6.3% to $5.32 billion—a pace that should easily give the paint industry a record $10 billion year.

Shipments of architectural coatings have lagged in the first half of 1986. After achieving a 3.8% increase

Three main paint categories break down this way

Architectural coatings
- Exterior house paints
- Interior house paints
- Undercoaters, primers & sealers
- Varnishes
- Stains

Product coatings[a]
- Wood furniture & fixtures
- Automotive
- Metal containers
- Machinery & equipment
- Factory finished wood
- Metal furniture & fixtures
- Sheet, strip & coil
- Nonautomotive transportation
- Appliances
- Electrical insulation
- Marine
- Film, paper & foil
- Pipe
- Toys & sporting goods
- Miscellaneous consumer & industrial products

Special-purpose coatings
- Automotive & machinery refinishing
- High-performance maintenance
- Traffic paint
- Roof coatings
- Bridge maintenance
- Aerosols
- Swimming pool coatings
- Arts & crafts
- Metallic coatings
- Multicolored coatings

[a] Original equipment manufacturers. **Source:** SRI International

in 1985 to 486 million gal, their growth rate in the first six months of this year has slipped to a level at which shipments are essentially level. In the January-through-June period, shipments of architectural coatings increased just 0.2%to 257 million gal.

Prices of architectural coatings, however, have risen. Though physical volume remained essentially the same in the first six months, the value of shipments increased 8.9% to $2.28 billion. This follows a rise in full-year 1985 of 12.2% to almost $4.11 billion.

The price increases for architectural coatings are apparent in the unit value (the government's estimate of the value of each gallon shipped). After dropping in 1982 and 1983, unit prices have increased. Following a modest 1% rise in the value per gallon in 1984 to $7.75 per gal, they rose 9% last year to $8.45 per gal. In the first half of 1986, the unit price for architectural coatings has climbed another 5% to an average value of $8.88 per gal.

The improved performance of the architectural coatings segment of the business may be somewhat surprising to long-term observers of the paint industry. This segment has been typically a lackluster part of the industry, showing little growth in volume and, because of the great number of producers, intense price competition. Also, producers say, the dominance of Sears in the retail end of the paint business also has served to keep prices in check. "Sears sets the market" is often heard in the paint industry.

Product coatings for the OEM sector accounted for about 33% of all paint shipments or 320 million gal in 1985. This represents a 5% increase in shipments over 1984. This sector has been growing relatively steadily since 1982. In the first six months of 1986, shipments of product coatings totaled 175 million gal, almost a 9% increase over the same period in 1985.

The value of these shipments also is rising, almost 7% in 1985 to $3.49 billion from the year before. Between 1982 and 1985, the value of product coatings climbed more than 40%. For the first half of this year, however, the shipments-value picture is not so rosy. In the first six months, the value of shipments totaled $1.84 billion, an increase of just 3% over the comparable period in 1985.

This, of course, reflects falling unit value in product coatings. The unit value for this segment of the industry, which goes largely into durable goods manufacture, has been slipping since 1984. Between 1984 and 1985, the value per gallon fell almost 0.5% to $10.67 per gal. This was followed by another drop of

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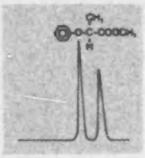

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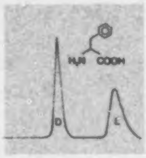

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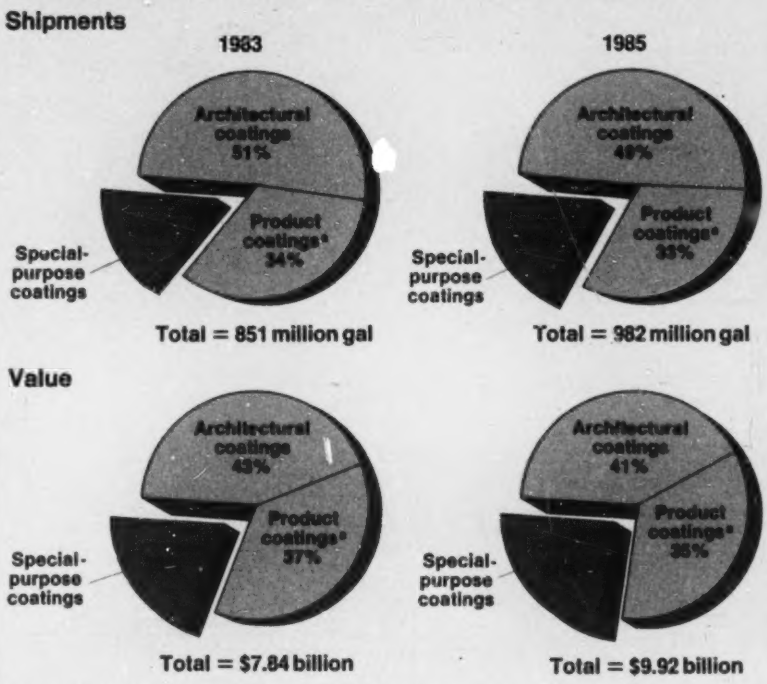
almost 2% through the first half of this year to $10.47 per gal.

The third segment of the industry, special-purpose coatings, which is the most diffuse in terms of end-use categories, has suffered a fate similar to that of product coatings, with shipments and the value of those shipments increasing, but the unit value declining, at least through the first half of this year.

According to the government data, shipments of special-purpose coatings increased more than 36% between 1982 and 1985 to 176 million gal, with almost 23% of that growth coming between 1984 and 1985. The results thus far for 1986, however, indicate that growth this year won't come close to equaling that of 1985. For the first half of 1986, shipments of special-purpose coatings totaled about 89.8 million gal, up less than 6% from the comparable 1985 period.

The increase in the value of shipments of special-purpose coatings

Architectural coatings still lead paint shipments and value, but edge is slipping as special-purpose coatings grow



[a] Original equipment manufacturers. **Source:** Bureau of the Census

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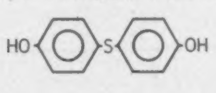

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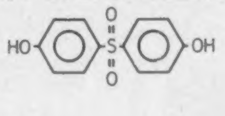

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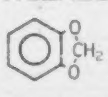

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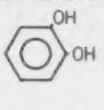

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outstripped shipments volume in the past few years, rising 66% between 1982 and 1985 to a total of $2.33 billion, with 30% of that growth from 1984 to 1985. For the first half of this year, the value of shipments totaled $1.2 billion, up less than 7% from the same period a year ago.

The unit value, according to the government figures, however, has not maintained a steady path upward. After increasing every year since 1982, including a 12% increase in 1985 to an average of $13.93 per gal, the average unit price for special-purpose coatings tailed off in the first half of this year, falling almost 4% from the average 1985 unit value to $13.38 per gallon.

The outlook for next year for the two big segments of the paint industry, industry sources point out, is a big question mark. They believe that consumption of architectural coatings probably will slow as growth in demand for single fami-

Bridges are major market for special-purpose coatings

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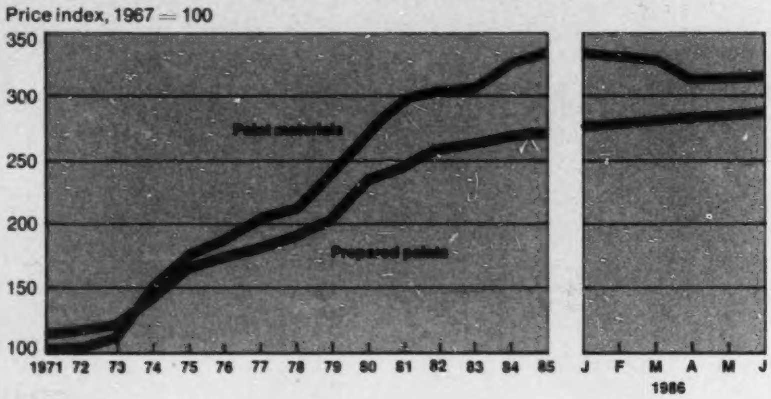
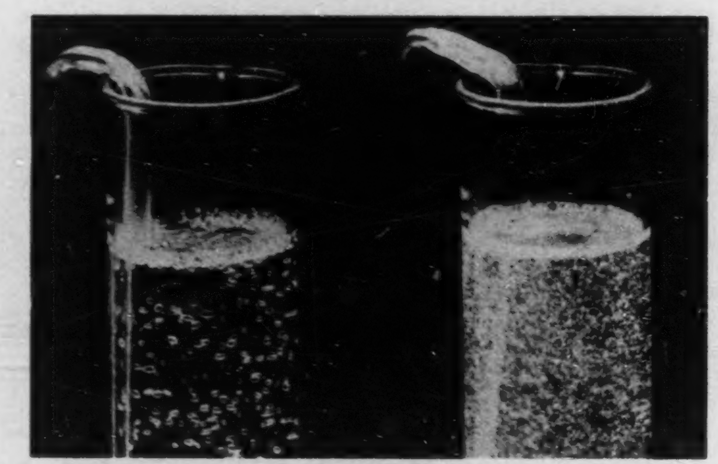
Raw material prices moved ahead of paint prices in early 1970s, but gap has narrowed recently



Source: Department of Labor

ly homes finally begins to abate. Construction of new office buildings also will slacken off as economic incentives are phased out in the new tax bill and as the current bulge of new office space in and around many major metropolitan areas remains unfilled. Apartment or multihome building also will decline as a result of the disincentives for construction in the new tax bill.

The outlook for product coatings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also is difficult to forecast but demand probably will be level or down in 1987. Auto output, which dominates this category, likely will be flat or down next year. Pundits say that many auto sales that would have taken place in 1987 have been advanced to this year as car makers sought to reduce inventories by offering attractive low-rate financing.

The tax bill also will have an effect here, as sales tax and interest on auto loans are no longer deductible. This, in effect, removes the government from subsidizing the purchase of automobiles and makes auto loans more expensive to the consumer. Whether lenders will lower rates to offset this increased expense is a question that as yet cannot be answered.

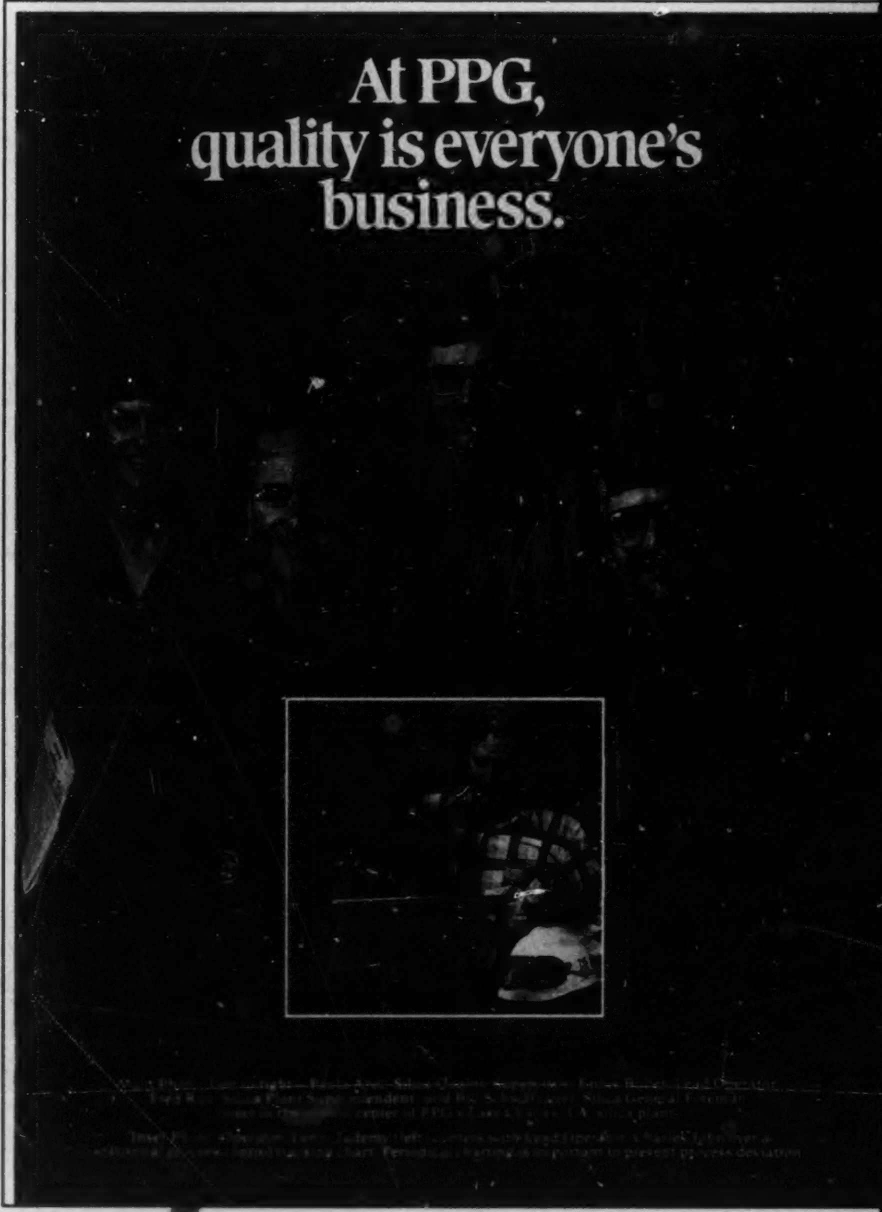
The third segment of the industry, special-purpose coatings, probably will continue its growth next year, at least in volume and probably in value. It is made up of a number of strongly performing end-use markets. Bridge maintenance paints, for instance, are in strong demand as funds continue for road and bridge maintenance. Maintenance coatings for industry also are enjoying good growth as companies continue to refurbish older manufacturing facilities. Industry concern about safety will keep fueling growth of safety-related coatings in this segment of the industry.

Another special-purpose coatings market, high-performance maintenance coatings, likely will continue to show growth at rates above that of the paint industry. According to a new study by WEH Corp., a San Francisco-based consulting firm, the demand for high-performance anticorrosive maintenance coatings in the U.S. probably will rise at an average annual rate of about 5.2% from about $720 million in 1986 to about $1.20 billion by 1996. The WEH study says this growth would be considerably better if not for a downturn in shipping activities and unattractive prospects for crude oil exploration.

Demand for these coatings will get strong upward pressure from markets such as hazardous material and sewage treatment, water storage, and bridges and highways, according to the WEH analysis. More moderate growth will come from defense and space, airlines and aircraft, pulp and paper, and electric and gas utilities.

Like the rest of the paint industry, this portion is going through consolidation and change. Besides ICI's acquisition of Glidden, the study cites Valspar's acquisition of Mobil's coatings division, RPM's acquisition of Carboline from Sun, Ameron's acquisition of Torpedo Marine, Grow's acquisition of Napko, and International Paint's purchase of Matcote.

In the past few years, the slow growth of the economy, especially in terms of big-ticket durable goods, the use of alternative exterior coatings such as vinyl and aluminum



siding for housing, and the more rapid increase of maintenance and other special-purpose coatings, has changed the share of the total paint market contributed by each of the paint segments. In 1983, architectural coatings accounted for 50.5% of total paint shipments. This dropped to 49.5% in 1985. At the same time product coatings fell from 34.3% in 1983 to 32.6% in 1985. But special-purpose coatings rose from 15.2% to 17.9% in those two years.

In terms of value of shipments, the change is even more dramatic. Architectural coatings made up 42.6% of the industry in 1983, but by 1985 their share had fallen to 41.3%. The drop for product coatings was even greater, from 37.4% in 1983 to 35.2% in 1985. However, special-purpose coatings increased their share of the paint industry from 19.9% in 1983 to 23.5% in 1985.

One bright spot for paint makers this year, especially for those producing solvent-based systems, is a drop in the price of raw materials. According to Labor Department figures, the producer price index for paint materials moved ahead of that for prepared paints in the mid-1970s, largely because of the increase in oil prices. In the past couple of years, both price indexes have flattened out considerably, until April of this year when the index for paint materials dropped about 5% from the previous month. This was almost entirely due to a 30% drop in the price index for paint solvents. Producers say this drop, like the rises before it, was related almost entirely to the price of oil. But the upshot is that for the past few months paint makers have been getting a break on raw materials while their own price index has increased ever so slightly, undoubtedly increasing margins for much of the industry.

Against a backdrop of higher-value-added products and greater sophistication, the industry itself, like the entire chemical industry, is changing. There is greater emphasis on specialization, on consolidation, and on technical service.

The paint industry, long made up of myriad small producers (estimates are that there are more than 1000 producers in the U.S. alone), is indeed becoming smaller in terms of the number of producers. Part of this results from consolidation, the most publicized of which have been the big mergers over the past few years, such as ICI's purchase of Glidden and BASF's buying of Inmont.

Another part of the decline in the number of manufacturers results from companies getting out of the business. Many of the small producers, especially of lower-specification products, are being forced out of the paint business by increased overhead costs. Skyrocketing liability insurance rates over the past few years, for instance, have raised the cost of doing business so much that small producers find it nearly impossible to make a profit. Add to

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Powder coatings may finally realize potential

Powder coatings, those solventless painting systems that have long been the unfulfilled hope of the paint industry, finally may be ready to start living up to their promise. At least this is the conclusion of Frost & Sullivan, the New York City-based market research firm.

The economic recovery and growing demand from a diverse number of industries are providing a setting for a turnaround in powder coatings in the U.S., according to a study by the firm. After failing to meet expectations and showing only an 8% growth rate since the 1970s, powder coatings have increased that rate and the total market is expected to reach 138 million lb by 1988, generating a real dollar volume of nearly $400 million. This is compared to a total 1983 market of 75 million lb and $178 million.

Frost & Sullivan says the powder coatings industry could see an accelerated rate of growth if it comes to grips with such issues as the development and consumer acceptance of coatings such as automotive topcoats, the use of high-speed powder curtain-coating methods, the greater promotion of powder coatings by major paint manufacturers, and domestic production of raw materials currently imported.

In Europe, Frost & Sullivan forecasts powder coatings growth at about 11% per year through 1988 as powder coatings come to be viewed less as alternatives and more as complements to wet paint systems, filling a niche in applications where relatively poor film flow and appearance can be used to some advantage.

In the U.S., the appliance and metal furniture and fixture sectors account for about 35% of the market. Machinery and equipment and construction have the greatest growth rate at about 17% per year. In Europe, tubular steel furniture accounts for about 23% of the market, but the fastest-growing area is the use of powder coatings for exterior-quality architectural finishes, where growth is predicted at about 20% per year.

that the cost of government safety, pollution control, and other programs, and profits are indeed wiped out.

In addition, industry sources say, much of the higher-value-added sector of the paint industry is becoming so sophisticated that the small manufacturer can no longer afford the development costs. Thus, the small producer can't compete with the big producer and its better technology.

As paint systems become more complex and as producers hope to garner greater margins on their products, both on the paint manufacturer and the paint material supplier sides, technical service to customers is taking on an increasingly important role. And this is a role that the small paint maker or paint material supplier cannot hope to fill.

This emphasis on new technologies and technical service is evident throughout the industry. At last year's Paint Industries Show held in St. Louis, John P. McAndrews, group vice president and head of finishes and fabricated products businesses at Du Pont, said that the paint industry must harness the technological expertise "that brought us so far so fast and use it to continue growing and, more important, to resolve key issues facing our industry." The industry issues he cited were the ones common to all of the chemical industry, having to do with increasingly stringent environmental and safety standards.

Earlier this year, Du Pont announced an expansion of its Troy, Mich., corporate automotive development center to "strengthen its support of the worldwide automotive market." At the center, the company will test high-performance coatings for plastics, metal, and oth-

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er substrates. The facility will simulate actual customer paint line conditions on full-size vehicles using sophisticated robotic equipment. The automotive paint sector is important for Du Pont. Du Pont says that, with its acquisition of Ford Motor's paint assets earlier this year, its paint sales to the auto industry total about $1 billion annually, or about 50% of the company's product sales to the automobile industry.

BASF's Inmont division is another company that is trying to serve Detroit better. Inmont has had a research and development laboratory in Southfield., Mich. Last month, however, it opened an applications research laboratory at the same site. The applications facility has two full-sized paint lines—one for spray and one for electrodeposition—to test technology in advanced coatings chemistry and paint applications before they are introduced in automobile assembly plants. Inmont says the new applications lab is planned to simulate any auto assembly plant painting configuration now used or planned.

Inmont senior vice president, automotive OEM coatings, Kennard A. Kinzler says auto makers are looking for suppliers with technical expertise and the ability to guarantee zero-defect performance, all with the greatest cost efficiency.

The shift to greater emphasis on marketing and technical service, which in the paint industry are becoming more closely related, is evident in employment figures for the industry published by the Labor Department. Between 1977 and 1985, total employment in the paint industry fell almost 4% to 63,600 employees. At the same time the number of production workers dropped 12.5% to 30,700 workers. This means that in that time span, nonproduction workers, which include technical support staff, marketers, and researchers among all other white-collar workers, rose 6.5% to 32,900

Dow chemist grinds powder coating formulation to fine powder

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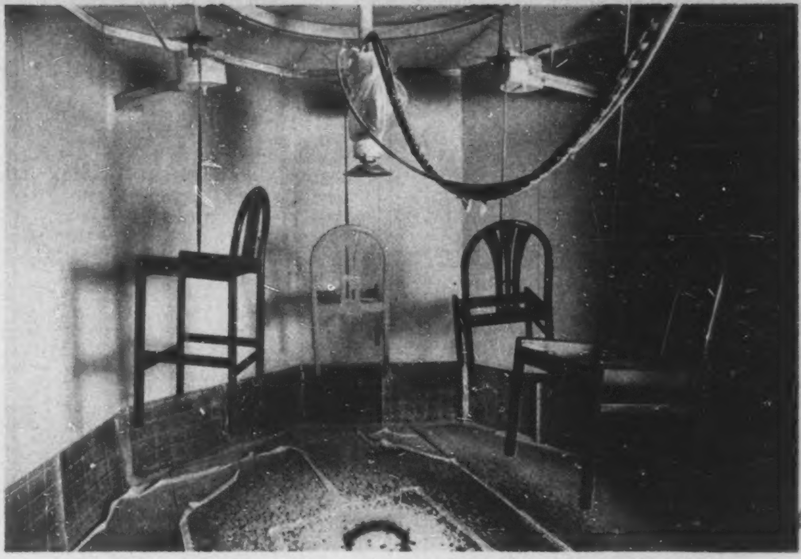
employees. Another way of looking at it is that, in 1977, nonproduction workers accounted for about 47% of total paint employment. In 1985, that percentage had increased to 52%. Even in the one-year span from 1984 to 1985, when chemical employment was increasing 2.6%, the number of production workers increased only 1% while the number of nonproduction workers rose a little more than 4%.

Many paint material suppliers have adopted technical service programs similar to those of the paint makers. The reasons are varied, and depend on the types of materials supplied. For instance, the programs can range from using technical support as a tool to overcome customer resistance to new materials or techniques to providing technical support to help in zero-defect and other quality-related programs.


Electrostatic disk painting system applies coating to wooden chairs

Dow Chemical, for instance, has instituted, among other technical service programs, a computer service designed to help paint and coatings makers solve problems with formulations containing glycol ether solvent. The company admits that the program, called CASS (computer-assisted solvent selection) service, is part of its efforts to assist paint and coatings formulators in making the transition, which has encountered customer resistance, from ethylene-based to propylene-based glycol ether solvents.

Robert Simmons, industrial marketing manager for Dow's chemi-

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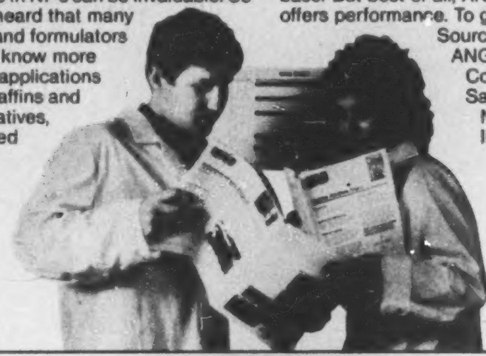

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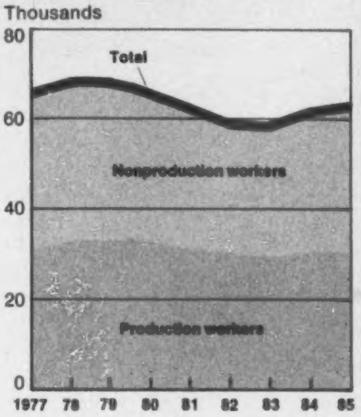
Nonproduction workers are making up bigger share of paint employment



Source: Department of Labor

cals and metals department, says this and other technical service operations performed by the company are largely problem-solving functions. A staff of technically trained field specialists work with formulators to solve problems with solvent systems. These support and marketing people carry personal computers, which include a program for data such as the evaporation rates and flash points of blends of solvents with different solubilities. This is backed by a technical service group at Dow's Walnut Creek, Calif., research facility.

Simmons notes that the program has been found useful by both large- and medium-sized paint manufacturers. He adds that, because solvents are basically commodity paint materials, the cost of the service must be made up in increased prices. Also, as is true for many commodities, there is a danger that once a formulation is developed for a manufacturer, the firm may switch to a supplier with lower prices.

This does not happen in the more specialty-oriented, higher-value-added part of the paint materials business.

At Mobay, which sells urethane systems to paint makers, the understanding is that when a customer buys a product, that customer is entering into a verbal contract that the product is for a particular use. As such, the product is expected to

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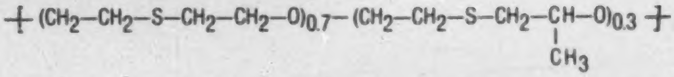
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meet customer specifications, and the supplier is obliged to ensure that it does.

Mobay has used this philosophy as a springboard for its technical service effort. Joseph S. Healey, marketing manager, Mobay's coatings division, says that the company's main thrust is forward marketing—helping the customer achieve new markets based on urethane systems. As such, the focus is work on resin development, formulation developments, and applications development. Special emphasis is placed on end-market development in conjunction with the customer.

The company employs a technically oriented staff of salesmen backed by a technical marketing organization. The marketing group is generally made up of people who have come out of the laboratory to provide the necessary technical information for the salesmen and the customers.

The major users of technical support, according to Healey, include the automotive industry and producers of architectural coatings of a high-value-added nature, bridge coatings, industrial and chemical plant coatings, and coil coatings that have more stringent requirements because of the rigorous conditions under which they are applied.

John L. Williams, technical marketing manager of industrial coatings, Mobay's coatings division, says that service is the key to overcoming problems and that Mobay has to involve itself in those problems if it is to introduce new technology.

His attitude is pervasive, especially in the higher-value-added sector of the materials business and the paint industry. And, as special-purpose coatings take on increasing importance, this attitude will become even more dominant. Also, the sophistication of systems for product coatings and the sheer size of the business make this segment a must candidate for increased technical service.

The problem, however, in many cases, ultimately will be who pays for technical service. According to some consultants, a time may come when technical service will no longer be done as a favor, but will be an integral part of the contract. □

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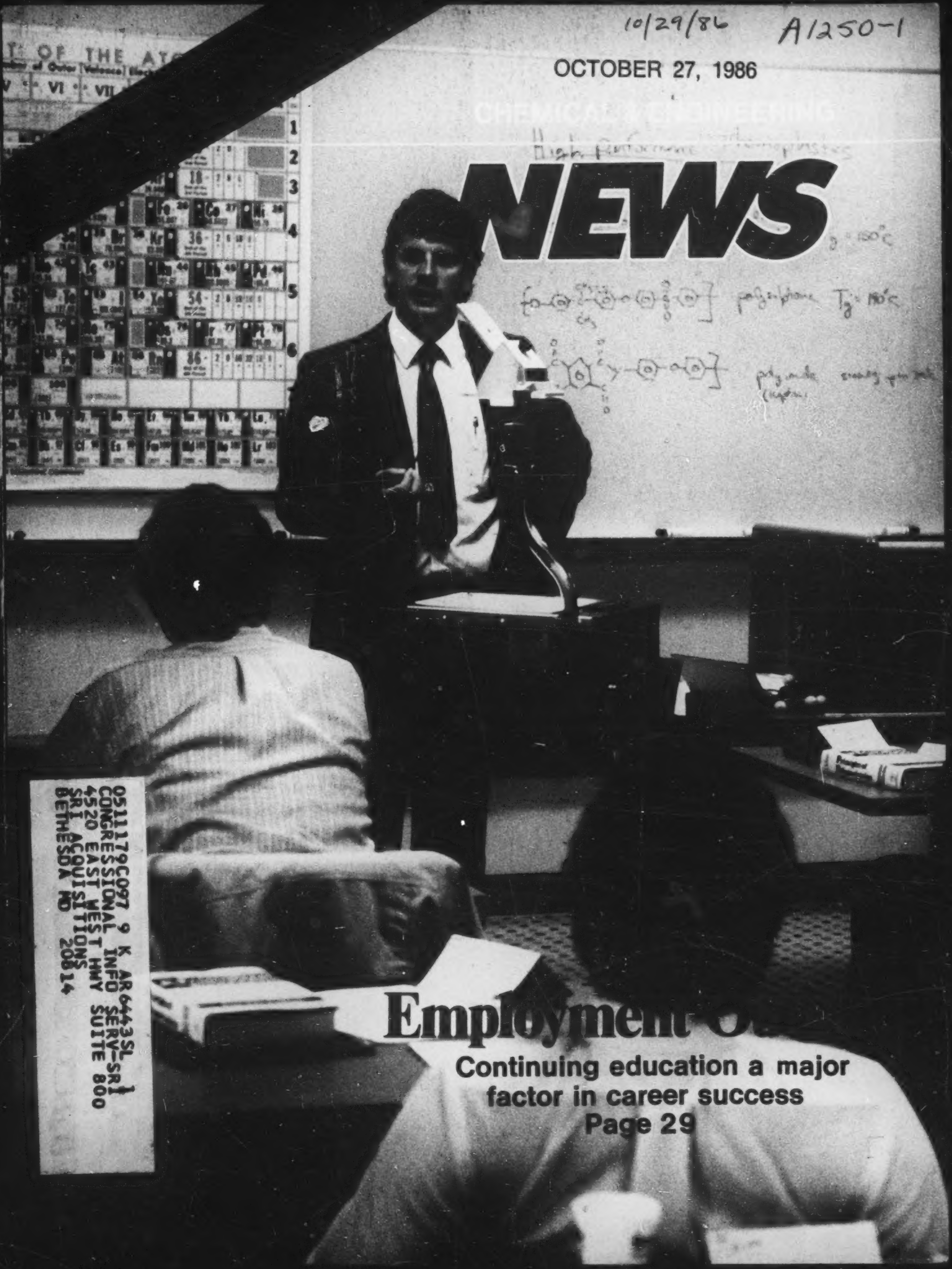
CHEMICAL & ENGINEERING

NEWS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Employment O

Continuing education a major factor in career success
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OCTOBER 27, 1986

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- **Third-quarter earnings are up for most U.S. chemical companies, even though sales are down in some cases.** **Page 7**
- **Robert C. Brasted, member of the ACS Board of Directors, dies of cancer at age 71.** **Page 8**
- **President Reagan reluctantly signs five-year, $8.5 billion Superfund bill into law.** **Page 8**

Cover: 3M scientist teaches continuing education course in advanced polymer chemistry to fellow employees

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International Business

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Employment Outlook

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European Executives Bullish Over Outlook for Petrochemical Industry

Favorable factors cited include improving economic growth prospects, freer market in oil prices, benefits of restructuring moves

Dermot A. O'Sullivan, C&EN London

William Shakespeare wrote, "What's past is prologue." It may have been with this premise in mind that the European Petrochemical Association's 20th annual meeting in Monaco recently chose its theme—the petrochemical industry over the past 20 years: have we learnt our lessons, and can we apply them in the future?

Jacques Puechal, president of Paris-based Atochem, one of France's leading petrochemical concerns, opened the session with a brief look back at how the French petrochemical industry has changed. In the mid-1960s, acetylene still was a basic material for making acrylonitrile, vinyl chloride, and the like, he points out. French ethylene capacity stood at about 900,000 tons a year in contrast with today's 2.48 million tons.

The rise in ethylene production stemmed from the rapid growth of fuel consumption, which in turn made naphtha available in large quantities and at a low price, he notes. "Furthermore, bulk plastics were developing, which increased demand for ethylene. This helped newcomers enter the business and build production sites beside existing ones."

The first attempts at restructuring the French petrochemical industry occurred in the 1970s with the emergence of ATO Chimie, Produits Chimiques Ugine Kuhlmann (PCUK), and Rhône-Poulenc, Puechal recalls. Based on overoptimistic demand forecasts, decisions were taken to put up new units. Although older ones were shut down, overcapacity continued because the rate of market growth slowed at about the time the new plants came on stream. Moreover, new producers outside the European Economic Community were coming onto the scene.

During the 1982 recession the situation became "catastrophic," as Puechal puts it. This led to the second reshuffling of the French industry under a government-inspired plan (C&EN, April 2, 1984, page 22). PCUK ceased to exist, and Rhône-Poulenc essentially withdrew from the business. Basic petrochemicals output in France now is confined to Atochem and CdF Chimie, together with British Petroleum, Exxon, and Shell, he notes. "Capacity reductions were accomplished, and this process is not necessarily at an end," Puechal notes.

"What happened in France may be seen as a special case," he says. "I don't think so. Building up, then restructuring the petrochemical industry has not been very different in other countries," he maintains.

"What seems to me of the utmost importance is our concern to continue strategic moves in the European petrochemical business. This is needed to maintain our competitiveness, to keep on upgrading our units, and to replace the aging ones.

"Some moves have been achieved in this direction during the past few years. Now we should not lose time, even if the present economic situation is more profitable to us. We have to improve our profitability so as to be able to [cope with] international competition and an ever-possible depression.

Puechal: continue strategic moves

"A fundamental change has been the emergence of newcomers in low-cost raw material countries or in areas with developing markets. Capacity is growing, and these newcomers are disrupting 'traditional' European markets and our export markets. These new producers will not give up, and we—Europe, Japan, and the U.S.—have to share the burden equally."

Turning to pricing policies, Puechal reminded his listeners that when there is an increase in raw material costs, it is difficult and takes time to transfer this to the price of the end products. On the other hand, when feedstock prices decrease, the lower cost is rapidly applied.

"Pricing stability can develop confidence of the downstream industry and increase the penetration of petrochemical products," he maintains. "Salesmen must have the nerve to resist buyers' arguments.

European ethylene, plastics capacity changed since 1980

Billions of lb	Capacity, end of 1980	Capacity, phased out 1980–86	Capacity added	Current capacity	Capacity change, %
Ethylene	40.00	12.72	2.76	30.04	−25%
Polyethylene, low density	14.76	3.60	—	11.16	−24
Polyethylene, high density	6.07	1.01	—	5.06	−17
Polypropylene	5.54	0.73	1.32	6.13	11
Polystyrene	5.20	0.68	0.33	4.85	−7
Polyvinyl chloride	13.10	1.87	0.33	11.56	−12

Source: EniChem

Trying to gain market share when there is overcapacity can deeply alter profitability of operations and bring new fluctuations." Nevertheless, Puechal professes confidence in the future of the petrochemical industry in Western Europe.

Also expressing optimism is Tom O. Hutchison, Imperial Chemical Industries' director in charge of petrochemicals and plastics with responsibility for continental Europe. "I associate myself with a moderate, yet rising, sense of optimism regarding the future of the industry in Europe," he says. "A number of significant factors are in our favor. It is up to us to take full advantage of them. If we don't, someone else in the world will."

The favorable factors he cites are a greater sense of economic realism within the industry, improving economic growth prospects, the freer market in oil prices, changes in Middle East developments, and the benefits arising from rationalization moves.

Throughout the 1960s, and during much of the 1970s, Hutchison recalls, a number of West European chemical producers decided to enter sectors of the industry and invested large sums of cash on projects that had little foundation in economic reality. "Price was often the only means of gaining market share, and resulting market disruption was commonplace," he notes.

"I now see signs that attitudes are changing," he says. "Many companies have achieved a substantial market position in selected products, and now have a considerable vested interest in market stability. In addition, governments, at one time guilty of profligate spending, are indicating a hardening attitude toward 'lame duck' projects. This new sense of realism is vitally needed throughout our industry, and must be maintained."

The price of oil, and the prospect for improvement in economic growth are interlinked. Oil now is priced at about $12 to $15 a barrel, roughly half what it was at its peak. The consensus is that it will remain at around the current level for some time.

"Although the Organization of Petroleum Exporting Countries is likely to re-establish greater influence in the 1990s, I believe its members have learned from the past, and that future oil price increases will be progressive rather than discontinuous," Hutchison predicts. "The prospects, at least for the next few years, are for oil to be influenced principally by a freer market. As a result, we will have to live with continuing oscillations in oil and gas prices. Those petrochemical producers who can accommodate greater flexibility in their feedstock use will see a handsome competitive dividend."

He acknowledges that the drop in crude oil prices late last year has not yet fed through to improved economic growth for the industrialized world. And although that growth unlikely will match "the heady levels" of the 1960s, he expects it to return to the rates of the 1970s, namely, annual growth of between 2.5 and 3% in gross national product. "That would be a notable improvement on the recent past," he points out.

Petrochemical producers will benefit in a number of ways, Hutchison says. For instance, energy costs now are back to the levels prevailing before the 1973 Arab oil embargo, and raw material costs have fallen substantially. Although the subsequent rise in profit margins is unlikely to be fully sustained, a significant improvement probably will be realized. Increasing demand probably will lead to higher levels of plant capacity use.

In contrast to the concern expressed a few years ago about threats from the buildup of petrochemical production in Saudi Arabia, Hutchison now feels more secure about the future. It is true, of course, that large tonnages of products from Saudi plants have found their way into Western Europe and that additional quantities have cut into markets long served by West European makers. "Much of this product now has been accommodated," he says, "and I foresee less of a threat arising from the plants under construction and yet to be started up there."

Substantial moves have been made in the past few years to bring production capacities of plants making ethylene and the bulk thermoplastics made from it more into line with anticipated demand and growth rates. These, together with restructuring steps, were highlighted by Charles M. Doscher, chief operating officer of Milan-based EniChem, the chemicals arm of Italy's Ente Nazionale Idrocarburi, when he addressed the European Chemical Market Research Association meeting in Antwerp recently. During the

Hutchison: attitudes are changing

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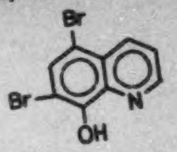

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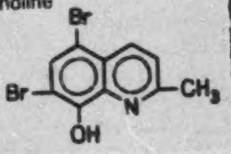

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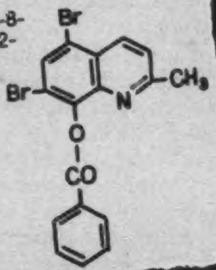

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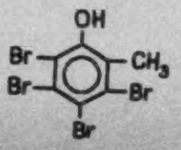

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past six years, for instance, ethylene capacity was pruned 25%, that of low-density polyethylene 24%.

The reductions have had a positive impact on capacity utilization. According to Doscher's figures, the average now stands close to 96% for polypropylene, 89% for LDPE/linear LDPE, 84% for both ethylene and high-density polyethylene, 83% for polystyrene, and 82% for polyvinyl chloride, based on nameplate capacities, which usually are 5 to 10% greater than the available capacities. The 1981 use rates, by comparison, were 75% for polypropylene, 62% for LDPE/LLDPE, 71% for ethylene, 64% for HDPE, 60% for polystyrene, and 64% for PVC.

"By a combination of attrition in capacity, buoyancy in the market, and an oil glut, the picture today looks less critical, and the industry less in need of major surgery. But before we all start congratulating ourselves and pronounce the crisis over, the margin improvement achieved has not left the bulk plastics' producers in a position where their returns on investment are sufficient to pay for rebuilding of aging plants," Doscher hastens to add.

"Since updating productive assets is an acid test of the health of any business, the point needs to be emphasized. I am not talking here of capacity additions, but the need for a 'scrap and build' policy that is just as much part of restructuring as plant closures."

ICI's Hutchison concurs, and voices concern about "the advancing age of the [European petrochemical] industry's assets. Many old plants have been closed. But there has been little opportunity to build new plants in the past five years, and the 'average plant' now is about mid-1970s vintage. There will in time be a growing and eventually urgent need for the replacement of existing assets.

"Few responsible [management] boards will be reaching for their checkbooks to replace bulk chemical plants even at today's somewhat improved level of return on investment. In the long term, this presents a problem for which I see no immediate solution other than the creation of a driving force for yet further concentration."

C&EN staff photo

Doscher: need scrap and build policy

In this connection, Hutchison points out, "there still are far too many producers of several important products." In the case of ethylene, for instance, the number has moved down only marginally to 28, from 31 in 1975. Likewise for HDPE, there are 16 now against 18 in 1975, 17 in polystyrene against 20. Indeed, the number making polypropylene has moved up to 16 from 11 over the same timespan. "Our colleagues in synthetic fibers have substantially changed the shape of their industry [in Europe]. We would do well to emulate them," he suggests.

"This brings up the sensitive issue of competition," Hutchison continues. "In Western Europe, there are many factors and attitudes in each country that make it difficult to achieve the restructuring which is necessary. While most of these can be overcome, more difficult are those aspects of competition policy within the EEC Commission that inhibit restructuring.

"There already have been some mergers and joint ventures within EEC," he admits, "which leads me to believe that neither national governments nor the commission are wholly opposed to the concept. But the process of receiving clearance or exemption from the commission is painfully slow."

He cites the case of his company's agreement to take over BP Chemicals' PVC operations in exchange for ICI's LDPE business in the U.K. "It took 18 months after the notification before exemption was announced," he recalls.

EniChem's Doscher maintains that "if management adopts a flexible and open-minded approach to the problems, we are going to be closer to a solution." He illustrates his point with two examples drawn from his own experience. One involved EniChem's leasing for 10 years the LDPE plant of Hoechst's Ruhrchemie subsidiary in Oberhausen, West Germany. At the same time EniChem phased out some LDPE capacity in Italy.

"The result has been quite positive," he points out. "Hoechst, which was seeking a way of getting out of LDPE without writing off expensive plant, has achieved its goal. EniChem wanted a Northern European production facility for strategic commercial reasons, but did not want to build additional capacity."

Doscher's other example centers on a joint venture between EniChem and ICI in PVC, called European Vinyls Corp. "Both companies were integrated producers. By leaving the assets with the parents, the two companies were able to construct a mechanism that allowed the right degree of flexibility at plant level while ensuring that the new venture had the necessary resources to fulfill its mission."

Looking to the future, Doscher maintains that "what needs to be done most is to examine carefully the way we approach innovation and specialized product segments. Today's commodities were specialties once, and those who ignore history are in great danger of repeating it. European companies need to be acutely aware of who is doing what in terms of innovation so that we don't duplicate each other's work.

"It is entirely possible that collaborative research and innovation approaches are the only way we can ever expect to create a healthy chemical industry over the next two decades. Only then can we have reasonable hope that managers of the 21st century will not need to undertake the painful rationalization that today's managers have come to regard as part of the job." ◻

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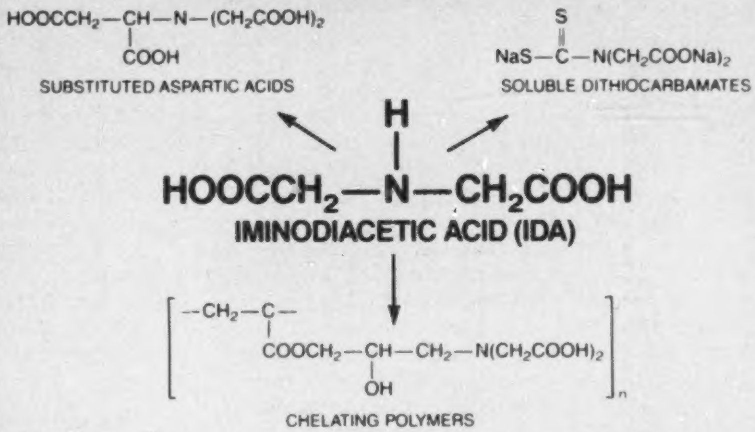

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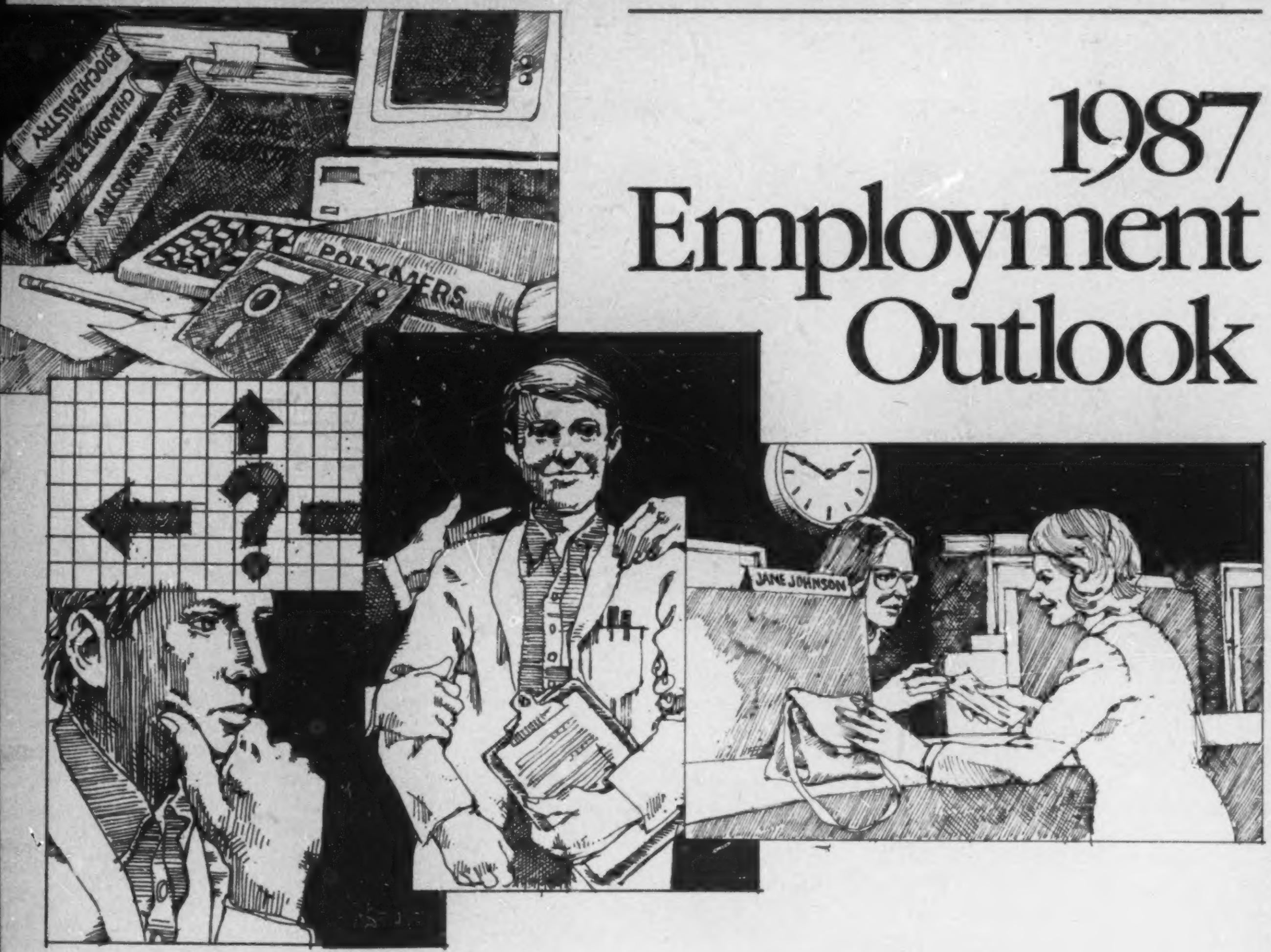
1987 Employment Outlook



Career Opportunities for Chemical Professionals

Chemists and chemical engineers generally found it harder to get jobs this year than they did in 1985. A sizable problem was that many large employers decided to reduce their costs by cutting back on their hiring of all types of employees, including chemical professionals. Especially hard hit this year were petroleum companies, whose profit picture had worsened to such a degree that they were able to offer chemists and chemical engineers relatively few positions.

The many large chemical firms that had instituted early-retirement programs to trim thousands of employees from their staffs could hardly have engaged in the brisk hiring that would have greatly helped the many chemical professionals who graduated this year from U.S. universities.

An indicator of the depressed job market for chemical professionals is the somewhat increased unemployment rate this year among members of the American Chemical Society and the American Institute of Chemical Engineers.

Continuing Education

Chemical firms are expanding their continuing education programs to improve the creativeness of their employees and to prevent them from falling behind in their professional knowledge. **Page 30**

Demand

The employment market for chemists and chemical engineers was disappointing this year, and many observers foresee little or no improvement in the situation in 1987. **Page 51**

Salaries

Median annual salaries of experienced chemists increased this year at all degree levels. Preliminary data show a decline in the salaries of inexperienced B.S. chemists. **Page 56**

Career Planning

The American Chemical Society and other organizations can provide a variety of useful information to people seeking advice about careers in chemistry and chemical engineering. **Page 58**

Demand

Cutbacks by employers in hiring of technical people have made job hunting more difficult this year for chemical professionals

Demand for chemists this year has been no cause for elation. Chemistry department spokesmen report that hiring of 1986 graduates, especially at the B.S. level, was "sluggish," "somewhat worse than last year," or "about the same as last year, which was not a particularly good time either."

As for chemical engineers of the class of 1986, demand for their services was better than it was a few years ago, but still a cause for concern. Chemical engineering departments report that 20 to 50% of their 1986 B.S. students did not have jobs when they graduated but were looking for them. This is in sharp contrast to the picture 10 or more years ago, when about every new job-seeking B.S. chemical engineer had a job at graduation.

The employment market for Ph.D. chemists and chemical engineers is better. At most schools, the vast majority of such Ph.D.s who wanted jobs found them, although some received only one offer. In former years, Ph.D.s in chemistry or chemical engineering typically could take their pick of several job offers.

Diminished demand for chemical professionals in 1986 also is reported by many leading chemical companies. The College Placement Council finds that the number of job offers received by chemists and chemical engineers is noticeably less in 1986 than in 1985. Unemployment among members of the American Chemical Society and the American Institute of Chemical Engineers is higher this year than last. The volume of position-open advertising in C&EN this year is less than in 1985, also reflecting reduced demand for chemical professionals.

A variety of reasons are blamed for below-normal demand for chemists and chemical engineers. In the recent past, low profits have led many companies to cut back on hiring of all types of employees, including scientists and engineers. Several years ago, when profits were considerably better and companies were growing rapidly, many firms tended to hire more people than they really needed. Now that revenues are much tighter, employers are under considerable pressure to trim their staffs.

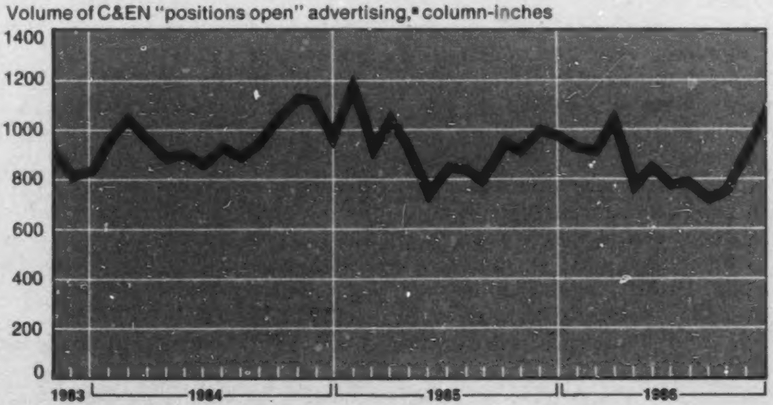
Many companies have been making determined efforts to increase productivity and efficiency, which boils down to achieving at least the same results with fewer people and less spending. Employers talk about running operations that are "leaner and meaner" and are stepping up efforts to combat competition from both the U.S. and abroad.

One major reason for currently disappointing job prospects for chemists and chemical engineers is the serious economic problems in the petroleum industry, which traditionally has employed large numbers of such professionals. These problems, of course, are related to recent sharp declines in the price of crude oil, as well as of gasoline and other petroleum products. These declines have cut deeply into profits of petroleum companies, forcing them to reduce staffing.

Likewise, reduced hiring has become commonplace in the chemical industry. In the past year or so, many firms have offered incentives to encourage the voluntary early retirement of thousands of their employees, including such major firms as Union Carbide, Du Pont, Monsanto, Eastman Kodak, and Dow Chemical. Newly retired chemical professionals often are competing with newly graduated counterparts in the job market.

Also making job-hunting more difficult for new chemistry and chemical engineering graduates is

Help-wanted ads below early-1985 high, despite upturn



a Column-inches published during consecutive periods of four weeks each; no issues were published in the last week of December 1983, 1984, and 1985.

the increasing number of mergers in the chemical and petroleum industries, such as Monsanto and Searle, Chevron and Gulf Oil, and Du Pont and Conoco. Almost inevitably when two companies merge, staff-cutting results to eliminate unnecessary overlapping of functions.

Most university chemistry departments contacted by C&EN indicate that 1985–86 graduates had a harder time finding jobs than did graduates in 1984–85. Audrey L. Aylesworth, placement coordinator in the chemistry department of the University of Wisconsin, Madison, reports that its B.S. graduates averaged 1.4 job offers in 1985–86, compared to 2.1 in the previous academic year. The average number of job offers was 1.5 for Ph.D. graduates in 1985–86, down from 2.6 in 1984–85, and 3.1 in 1981–82.

Aylesworth states that, from talking with recruiters, she got the impression that many companies interviewing the chemistry department's graduates were doing so not to expand their research staffs but rather to find a few specialized people to replace those who had retired or resigned in the past year.

She also believes that the job market for chemists at the University of Wisconsin, Madison, might have been worse in 1985–86 if it were not for the fact that the number of candidates seeking industrial employment was less than in the previous academic year. In 1985–86, the number of Ph.D. candidates using the placement service was only 29, compared to 39 in 1984–85.

At the school of chemical sciences of the University of Illinois, Urbana, (which includes both chemistry and chemical engineering) the number of employers who visited the campus to interview graduating students was 22% less in 1985–86 than in 1984–85. Because quite a few students could not get as many on-campus interviews as they wanted, the number of résumés that the school mailed directly to employers (the so-called "overflow") was 82% greater in 1985–86 than in the previous academic year.

Rebecca J. Simon, placement director of the school of chemical sciences, reports that 14% fewer job offers were made to graduating Ph.D. chemists in 1985–86 than in 1984–85. On the other hand, 65% more job offers were made to B.S. chemists in 1985–86 than in 1984–85. She attributes the brighter fortunes of B.S. chemists partly to the fact that many of them looked for and accepted jobs in such nonresearch areas as sales, marketing, or technical service.

Nevertheless, many B.S. chemists graduated from Illinois with considerable uncertainty about their futures. Only 62% had reported definite plans at graduation to take jobs, begin graduate work in chemistry, or enter medical or dental school. The percentage of 1986 B.S. chemical engineers who also had reported definite plans was slightly lower—58%.

A few Illinois students who graduated this past spring had accepted job offers from petroleum companies in late 1985. Within a few months, however, they found that their offers were withdrawn because of worsening business conditions or were told that they would be the first to be let go in the event of a company layoff. These students, Simon says, were placed in a serious predicament because, by this time, on-campus recruiting had practically come to an end.

R. Bryan Miller, chairman of the chemistry department at the University of California, Davis, describes the job market for its 1985–86 B.S. graduates as "soft," certainly not so good as it was three or four years ago. Although some of the students who were not going on for postgraduate study did not have jobs when they graduated, all of them have jobs now, Miller believes.

As for the department's 1985–86 Ph.D. graduates, almost all now have permanent jobs or postdoctoral positions. Almost none of the department's recent graduates got jobs with petroleum companies, which in the past had hired significant numbers of them, particularly because of the university's location on the West Coast.

At the University of Colorado, says Bert M. Tolbert, associate chairman of the chemistry department, B.S. chemists who graduated last spring found jobs slightly more difficult to get than did such chemists in the spring of 1985. The employment market was strong for Ph.D.s in analytical chemistry, he says, but unchanged for Ph.Ds in other chemical disciplines.

Quite a few of the department's graduating B.S. chemists in 1985–86 did not bother to look for jobs until after graduation. One reason may have been a preoccupation with studies or a belief that they could rely on their affluent parents to support them until they found employment. Another explanation is their discouragement over the state of the job market.

The number of companies that sent recruiters to the University of Michigan's chemistry department fell 13% from 1984–85 to 1985–86. Plant visits made by recent graduating students and the number of job offers they received also have decreased noticeably. On the other hand, more campus visits are being made by recruiters from companies involved in solving toxic waste disposal problems. "This," says Leah C. Atwater, director of the department's student services, "is obviously a growth area for chemists."

In the face of a weak job market, graduating chemistry students, Atwater indicates, are having as many campus interviews as possible. They also are mailing out considerably more résumés than usual to companies on their own. "Clearly, they are working much harder at getting a job," she says.

Demand for 1985–86 chemistry graduates at the University of Massachusetts, Amherst, was "spotty and not as strong as in 1984–85." Robert L. Rowell, chemistry professor and until recently acting department head, notes that company recruiters seemed to know precisely what kinds of people they wanted to hire and were unusually selective in making job offers. The sharp economic downturn in the petroleum industry, he says, "practically wiped out hiring of chemists by some oil companies and also resulted in the firing of chemical employees. The situation was a disaster."

The job market probably is even more disappointing for new chemical engineers. At Texas A&M, only about half of the 1985–86 B.S. chemical engineers had jobs when they

Demand for chemical professionals declines this year

The job market for both chemists and chemical engineers is clearly less active in 1986 than in 1985. A recent C&EN survey of 25 employers of chemical professionals indicates that they intend to hire 25% fewer chemists and that 14% fewer chemical engineers will be hired this year compared with last year. On the other hand, the employers surveyed plan to hire 22% more chemists and 13% more chemical engineers in 1987 than in 1986.

One company representative comments, "We find that we work better with leaner staffing." Another employer adds, "The continued low growth in the chemical industry and depressed crude oil prices have dictated moderation in our hiring of chemists." "Our sales volume has not increased enough to encourage us to enlarge our staffs in research and manufacturing," another observes.

But looking at future demand for chemists, one company spokesman states, "Our hiring of chemists next year should be back up at the 1985 level." Another predicts "an upturn in our hiring next year." A third comments, however, "In 1987, we plan to hire only replacements to maintain the current size of our technical staff."

The prevailing business climate has affected their hiring of chemists greatly, nearly half of the survey respondents admit. Only 20% think it has had slight impact or none at all.

Most of the employers of chemical professionals surveyed by C&EN are chemical or petroleum companies; a few are research firms. These organizations, as of mid-1986, employed about 13,000 chemists and about the same number of chemical engineers. Women accounted for about 17% of the chemists and about 12% of the chemical engineers.

About 63% of the chemists they plan to hire this year will be new graduates, compared to 56% last year. Of the chemical engineers they plan to hire this year, about 76% will be new graduates, compared to about 80% in 1985. Says one employer, "Prevailing business conditions in the chemical field have reduced our hiring of inexperienced chemists. Instead, we are tending to hire experienced candidates to replace employees who have resigned or retired."

The organizations surveyed made 4% fewer visits to college campuses to recruit chemists in 1985–86 than in 1984–85 and expect visits in 1986–87 to drop another 3%. In their search for chemical engineers, 10% fewer visits were made to college campuses in 1985–86 than in the previous academic year and 2% fewer visits will be made in 1986–87 than in 1985–86.

More than 80% of employers are seeking specialists in particular fields of chemistry. The specialists most frequently cited are (in decreasing order) organic chemists, analytical chemists, polymer chemists, physical chemists, and biochemists.

Asked what the employment outlook for chemists will be in their organizations during the next five years, 17% said it is excellent or very good, 61% said good, and 22% fair. For chemical engineers, 23% said the job outlook is excellent or very good, 50% said good, and 27% fair. None think the outlook for chemists in their firms is poor.

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graduated, although the vast majority of them were looking for industrial employment. The situation was about the same as in 1984–85. Ronald Darby, professor of chemical engineering at Texas A&M, points out that some B.S. chemical engineers who graduated in May 1986 are still looking for jobs.

The task of finding a position does not appear to have been eased, he says, by the decreasing number of B. S. chemical engineering graduates. Texas A&M awarded B.S. degrees to 138 chemical engineers in 1983–84, but to only 100 in 1985–86. It expects the number to drop to 50 in 1986–87.

The size of the graduating class is expected to decline still further in the years ahead. Darby mentions that the current freshman class in chemical engineering has less than 100 students. At its peak in 1981–82, the freshman class numbered about 350.

Because of the tight job market, some of the university's recent graduating B.S. chemical engineers have had to accept unconventional jobs, says Darby. One or two have taken positions with state environmental agencies. Some have gone into real estate or have joined family-owned businesses.

The chemical engineering department at Virginia Polytechnic Institute & State University reports that the employment situation for its B.S. graduates has improved in the past few years but is still less than satisfactory. William L. Conger, head of the chemical engineering department, says that the percentage of B.S. graduates who had jobs or were planning to enter graduate school at the time they got their degrees in May rose from about 30% in 1983 to 70% in 1985 and 1986. The figure is also expected to remain about 70% in 1987.

At the same time, B.S. graduating classes in chemical engineering at Virginia Tech are shrinking. The department graduated about 90 B.S.s in 1985 and 75 in 1986. Next year, it expects to graduate about 50. Conger believes that this decrease thus far has had little effect on the number of new graduates who are able to find industrial jobs. The impact of such shrinkage, however, may well be felt in the years ahead, he says, if the number of graduates falls to seriously low levels.

Of 32 B.S.s who graduated from Cornell University's school of chemical engineering in 1985–86, 13 had jobs at graduation, 14 planned to go to graduate school (in some cases, because they had gotten no job offers), and five were still looking for positions. Citing the companies that had hired its 1985–86 B.S. graduates, the school's recent newsletter states pointedly, "Note the absence of oil companies in this list."

Cornell also has been graduating fewer B.S.s in the past few years. It awarded only 32 B.S. degrees in 1985–86, down from 59 in 1984–85.

The downturn in demand for chemists and chemical engineers

Undergraduate degrees decline slightly while slightly more graduate degrees are awarded in chemistry

Academic year	Degrees awarded in chemistry[a]			Degrees awarded in chemical engineering		
	Bachelors	Masters	Ph.D.s	Bachelors	Masters	Ph.D.s
1973–74	10,525	2138	1828	3454	1045	400
1974–75	10,649	2006	1824	3142	990	346
1975–76	11,107	1796	1623	3203	1031	308
1976–77	11,322	1775	1571	3581	1086	291
1977–78	11,474	1892	1525	4615	1237	259
1978–79	11,643	1765	1518	5655	1149	304
1979–80	11,446	1733	1551	6383	1271	284
1980–81	11,347	1654	1622	6527	1267	300
1981–82	11,062	1751	1722	6740	1285	311
1982–83	10,746	1604	1746	7145	1304	319
1983–84	10,704	1667	1774	7475	1514	330
1984–85	10,550	1680	1875	7000	1350	335

a Data do not include biochemistry and geochemistry. b C&EN estimates. **Source:** Department of Education's National Center for Education Statistics

shows up in figures from employers themselves. An unusually dramatic example of this is reported by Du Pont, which hired only about 30% as many chemists in 1985–86 as in 1984–85 and only about 40% as many chemical engineers. In 1986–87, however, Du Pont expects to return hiring of chemical professionals to 1984–85 levels.

Robert K. Armstrong, manager of professional staffing at Du Pont, says that the sharp cutback in chemical hiring in 1985–86 reflected a major companywide effort to increase productivity. As part of this effort, Du Pont temporarily instituted a voluntary early-retirement program.

Thomas J. Neelan, manager of university relations at Union Carbide, says Carbide's hiring in 1985–86 dropped because of a concerted company effort to reduce overall staffing and operate more efficiently. To reduce its employment, Carbide also adopted a temporary early-retirement program.

Ted J. Logan, manager of Procter & Gamble's Ph.D. recruiting, notes that many major companies these days are increasing their emphasis on life sciences and various engineering disciplines, with a corresponding decrease in emphasis on chemistry. As a result, they currently are tending to hire fewer chemists and more life scientists (pharmacologists, cell and molecular biologists, biochemists, immunologists) and engineers (chemical, ceramic, electrical, and bioengineers).

Most observers believe that the job market for chemists in 1987 either will be about the same as in 1986 or will be slightly better. Aylesworth of the University of Wisconsin, Madison, foresees "no great upturn or downturn." Simon of the University of Illinois comments, "I think we can expect about the same amount of recruiting activity in 1987 as in 1986, even though my industrial contacts are indicating that hiring will be up slightly."

Atwater of the University of Michigan comments, "I am guardedly optimistic that we will see a modest improvement in the employment picture for chemists in 1987." Rowell of the University of Massachusetts, Amherst, predicts, "The job market should be slightly better in 1987. Assuming the price of oil increases and profits in the petroleum industry improve, petroleum companies next year should start hiring more people, including chemists."

Less optimistic, one company spokesman believes that industry's demand for Ph.D. chemists will be about 10% less in 1987 than in 1986, mainly because of disappointingly low R&D budgets, relatively poor company profits, and inadequate cash flow. The task of finding a job will be especially difficult, he says, for Ph.D. chemists who are in the bottom quarter of their class academically or are from less prestigious schools.

As far as the market for new chemical engineers is concerned, Darby of Texas A&M notes, "I don't expect the job situation for our B.S. chemical engineers to be any worse in May 1987 than it was in May 1986. In fact, it may be a little bit better. According to my discussions with recruiters from both the chemical and petroleum industries, the job market appears to have leveled off or improved somewhat." Conger of Virginia Tech reports, "The recruiters I have spoken with in recent months say that the demand for new chemical engineers in 1987 will be about the same as in 1986."

William Dausses, director of employment and placement at Phillips Petroleum, observes, "The demand for chemical engineers should improve slightly next year, as the need for their talent increases among companies involved in chemical manufacture, petroleum refining, R&D, pollution abatement, and so on."

In its latest employment report, covering 12-month periods, the College Placement Council indicates that new B.S. chemists received 12% fewer job offers as of July 1986 than as of July 1985. New Ph.D. chemists received 36% fewer offers. B.S. chemical engineers got 37% fewer offers and Ph.D.s 44% fewer.

As of July 1986, the B.S. scientists who received the most offers were computer scientists and mathematicians, according to the council. The B.S. engineers who fared best were electrical (including computer) engineers and mechanical engineers.

The council also reports that, as of July 1986, male B.S. chemists received the same number of job offers as they did in the 12 months ending July 1985, but women B.S. chemists got 22% fewer offers. Male B.S. chemical engineers got 35% fewer offers as of July 1986, and women B.S. chemical engineers received 41% fewer.

As further evidence of the weakening job market for chemists, the overall unemployment rate for ACS-member chemists rose from 1.4% on March 1, 1985, to 1.7% on March 1, 1986. The unemployment rate for ACS-member chemists on March 1, 1986, was 2.6% for B.S. chemists, 1.7% for M.S.s, and 1.3% for Ph.D.s, compared to 2.0% for

B.S.s, 1.6% for M.S.s, and 1.1% for Ph.D.s on March 1, 1985.

The American Institute of Chemical Engineers likewise reports that the overall unemployment rate among its members rose from 2.8% in February 1985 to 3.2% in February 1986. The comparable figure was 4.3% in February 1983, when unemployment among AIChE members was at the highest level since the institute began surveying its members in 1971.

Audra B. Rafter, manager of the ACS Employment Aids Office, which operates the ACS National Employment Clearing House, describes the atmosphere and general feeling among employers and job applicants at the latest clearinghouse at Anaheim, Calif., in September as better than at the clearinghouse in Chicago in September 1985. Especially noteworthy, she says, is the fact that the number of employer representatives at Anaheim was 217, which was higher than expected in light of the slow employer activity earlier in the year.

At the Anaheim clearinghouse, the types of job applicants that recruiters were primarily interested in were analytical chemists (110 positions listed), organic chemists (44), polymer chemists (41), biochemists (27), chemical engineers (22), physical chemists (16), and teachers (14).

The volume of "position-open" advertising in C&EN this year also reflects a downturn in the demand for chemical professionals. The number of column-inches of such advertising in the first 44 issues of 1986 was 9534—6% lower than in the first 44 issues of 1985.

Deutsch, Shea & Evans, a human resources advertising firm, reports that its high-technology recruitment index (based on the volume of recruitment advertising directed to scientists and engineers) rose from 105 in July 1985 to 116 in February 1986 but then fell to 105 in July (a slight increase from 103 in the previous month). Marjorie Freedland, vice president of DS&E, comments, "We'll have to wait until the major corporations have stopped trimming their technical staffs before we can announce that the long-awaited turnaround in technical recruitment has begun." □

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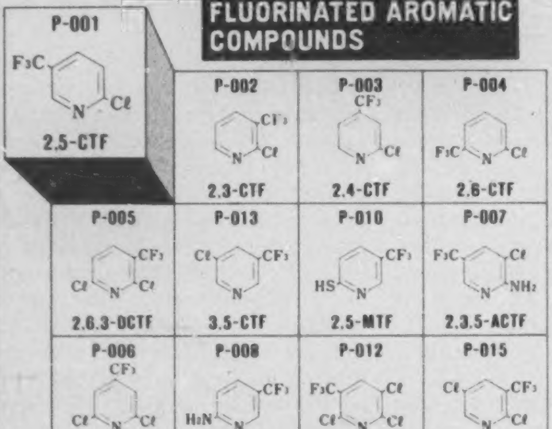

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